Wyoming Geo-notes
Number 79

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Wyoming State Geological Survey
Lance Cook, State Geologist

Laramie, Wyoming
March, 2004

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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.

People with disabilities who require an alternative form of communication in order to use this publication should contact the Editor, Wyoming State Geological Survey at (307) 766-2286. TTY Relay operator 1 (800) 877-9975.

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600 copies printed by Pioneer Printing and Stationery Company, Cheyenne, Wyoming.

Front cover: "Earthquake Camp," 1871 photograph by William Henry Jackson during the Hayden Survey expedition to the Yellowstone area. According to Jackson's "Descriptive Catalog of Photographs of the United States Geological Survey, Years 1869 to 1875," this is photograph #288 and is an albumen print on a Hayden Survey mount, from an 8" x 10" glass plate negative. Jackson's description reads, "Earthquake Camp, near Steamy Point, east side of Yellowstone Lake, so named from several slight shocks of earthquake which were experienced at this place on the night of the 19th of August, 1871." Interestingly, these were the first recorded earthquakes in Wyoming. Photograph from the private collection of Lance Cook, Wyoming State Geologist.

MINERALS UPDATE

Overview

Lance Cook, Wyoming PG-2577

State Geologist, Wyoming State Geological Survey

Mineral production in Wyoming for the third quarter of 2003 was on track or higher than our year-end projections. Natural gas, coal, trona, and uranium production for 2003 should all equal or exceed last year's production (**Table 1**), but the gains are all modest, in the range of a 1 or 2% increase. Oil production continues to decline each year, as expected, but because of the carbon dioxide flooding projects in some major oil fields, the rate of decline is expected to lessen. Other minerals produced in Wyoming, such as bentonite, gypsum, aggregate, and sand and gravel should equal last year's production.

Prices for Wyoming's major minerals are better than predicted, as the third quarter of 2003 showed (see the individual mineral update articles in this issue for details). Oil prices for the year may be more than $1.00 per barrel higher than projected, natural gas about $0.21 per thousand cubic feet higher, and coal at least equal to our projections (**Table 2**). Even the price of yellowcake, the refined product from uranium mining, was up substantially in the third and fourth quarters, rising from $10.90 per pound to $14.50 per pound.

It was encouraging to see spot prices for Powder River Basin (PRB) coal, which have remained at about the same level for over a year, jump almost $1.00 per short ton in the third quarter, as demand picked up substantially in the second half of 2003. This is good news for the coal industry, especially for new contracts that were inked in the third and fourth quarters and will carry the higher prices into the future. The **Coal Update** also reports a new, patented process for removing mercury from flue gas emissions in coal-fired power plants. The state's industry has been concerned about the mercury problem in burning Wyoming coal and the new process is reportedly quite effective on low rank coals.

Industrial minerals produced in Wyoming for the third quarter of 2003 are all on track to equal or exceed last year's production. A dimensional stone quarry reopened near the Wyoming State Penitentiary in Rawlins and hopefully will be used for some of the many new construction projects in Wyoming and surrounding states. Trona produc-

Table 1. Wyoming mineral production (1987 through 2002) with forecasts to 2008[1].

Calendar Year	Oil[2,3]	Methane[3,4]	Carbon Dioxide[3,4]	Helium[4,5]	Coal[6]	Trona[7]	*In situ* Uranium[8]
1987	115.9	628.2	114.2	0.86	146.5	12.4	0.00
1988	114.3	700.8	110.0	0.83	163.6	15.1	0.09
1989	109.1	739.0	126.1	0.94	171.1	16.2	1.1
1990	104.0	777.2	119.9	0.90	184.0	16.2	1.0
1991	99.8	820.0	140.3	1.05	193.9	16.2	1.0
1992	97.0	871.5	139.2	1.05	189.5	16.4	1.2
1993	89.0	912.8	140.8	1.06	209.9	16.0	1.2
1994	80.2	959.2	142.6	1.07	236.9	16.1	1.2
1995	75.6	987.5	148.8	1.11	263.9	18.4	1.3
1996	73.9	1023.4	149.0	1.10	278.4	18.6	1.6
1997	70.2	1040.7	151.0	1.10	281.5	19.4	2.2
1998	65.7	1072.6	151.0	1.10	315.0	18.6	2.3
1999	61.3	1133.1	161.0	1.10	336.5	17.8	2.8
2000	60.6	1293.3	161.0	1.10	338.9	17.8	2.1
2001	57.5	1437.6	174.0	1.20	368.8	17.7	1.6
2002	54.7	1572.6	174.0	1.20	373.2	17.2	1.4
2003	52.5	1602.8	196.0	1.20	376.8	18.0	1.4
2004	50.4	1602.8	196.0	1.20	380.6	18.0	1.4
2005	50.4	1652.8	196.0	1.20	384.4	18.5	1.4
2006	52.4	1707.8	196.0	1.20	388.3	18.5	1.4
2007	54.5	1765.5	196.0	1.20	392.1	18.5	1.4
2008	57.7	1824.3	196.0	1.20	396.0	18.5	1.4

[1]From CREG's Wyoming State Government Revenue Forecast, October, 2003; [2]Millions of barrels; [3]Wyoming Oil and Gas Conservation Commission, 1987 through 2002; [4]Billions of cubic feet, estimates for methane include 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, 1987 through 2002); [7]Millions of short tons (Wyoming Department of Revenue, 1987 through 2002; Wyoming State Inspector of Mines, 2002); [8]Millions of pounds of yellowcake (Wyoming Department of Revenue, 1987 through 1999; Wyoming State Inspector of Mines, 2000 through 2002).

Table 2. Average prices paid for Wyoming oil, methane, coal, and trona (1987 through 2002) with forecasts to 2008[1].

Calendar Year	Oil[2]	Methane[3]	Coal[4]	Trona[5]
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	5.40	37.28
2001	21.59	3.66	5.75	38.00
2002	22.08	2.09	6.66	38.00
2003	25.75	4.20	6.80	37.50
2004	22.50	3.50	6.00	37.50
2005	20.50	3.25	6.03	37.50
2006	20.50	3.25	6.12	37.50
2007	20.50	3.25	6.24	37.50
2008	20.50	3.25	6.40	37.50

[1]From CREG's Wyoming State Government Revenue Forecast, October, 2003; [2]First purchase price in dollars per barrel (weighted average price for sweet, sour, heavy, stripper, and tertiary oil). Source: Energy Information Administration, 1987-2002; [3]Wellhead price in dollars per thousand cubic feet (MCF), includes coalbed methane. Source: American Gas Association, 1998-2002; Wyoming Office of State Lands and Investments, 1989-2002 (derived from State royalty payments); and Minerals Management Service, 1987-1988 (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, 1987-1990 and derived from Wyoming Department of Revenue, 1991-2002; [5]Dollars per ton of mined trona, not refined soda ash. Source: Wyoming Department of Revenue, 1987-2002.

tion and soda ash refining remains healthy despite the shutdown of FMC's Granger operation. Wyoming may still be considered to supply silica sand for a Budweiser beer bottle plant near Fort Collins, Colorado, but so far, nothing has been decided or announced.

The Metals and Precious Stones Section at the Wyoming State Geological Survey (WSGS) could be called upon to do an economic evaluation for the State of Wyoming on its newly acquired Carissa gold mine property at South Pass. The State is exploring ways to develop or utilize this mine, including possibly incorporating it into the South Pass Historic Site or exploiting the gold resources that may be present (but yet to be evaluated). Interest in iolite and other colored gemstones is increasing for the central Laramie Mountains, where a number of excellent gem-quality iolites have been recovered, along with some rubies and sapphires. The **Rock Hound's Corner** of this issue focuses on the mineral iolite.

Work on STATEMAP 2003 projects continues and the WSGS proposal for STATEMAP 2004 was submitted to the U.S. Geological Survey (USGS) in November, 2003. A number of WSGS sections will again be involved in proposed STATEMAP projects, including the Mapping, Publications, Metals and Precious Stones, and Industrial Minerals and Uranium sections. Our proposal for STATEMAP 2004 is detailed in the **Geologic Mapping, Paleontology, and Stratigraphy Update**.

The Geologic Hazards Section at the WSGS has been working with the Federal Emergency Management Agency to revise, update, and remap the flood-prone areas of Wyoming and generate Flood Insurance Rate Maps (FIRMs). In the **Hazards Update** section in this issue of *Wyoming Geo-notes*, this project is described and the results of some of the ongoing work is shown. A business plan for this project became available in March, 2004 and is published as WSGS Open File Report 2004-2.

Finally, this issue of *Wyoming Geo-notes* contains a short article on paleo-stream channel deposits in the Rattlesnake Hills area of central Wyoming. These deposits, now preserved as benches or gravel-capped terraces, help document a number of tectonic events in the middle and late Tertiary that not only created a large uplift and mountain range in central Wyoming (the Ancestral Granite Mountains) but also caused its later subsidence and destruction. This mountain range may have had peaks on the order of 11,000 feet in elevation, depending on the regional elevation of central Wyoming in earliest Miocene time, and may have subsided a minimum of 3200 feet in the late Cenozoic.

Fossil exchange with the Field Museum

The WSGS and Office of State Lands and Investments (State Lands) are pleased to announce an agreement to exchange fossil specimens with the Field Museum of Chicago. The agreement will benefit both Wyoming's citizens as well as the Field Museum. The agreement will bring to the State of Wyoming several display-quality items including a resin cast of a 13-foot crocodile (**Figure 1**); a resin cast of a 6-foot turtle specimen (**Figure 2**); and a large *Notogoneus* with *Priscacara* (species of fish).

The two large casts are of two of the most spectacular, exhibit-size specimens to come out of the Green River Formation of Wyoming. The casts are being prepared by the Geology Museum at the University of Wyoming, where they will be on display for the public to enjoy.

In exchange, State Lands has authorized the WSGS to offer seven specimens of fossil fish, partially prepared and not of exhibit quality. The Field Museum is a leading research center in the investigation and description of fauna from the Green River Formation, and desired the state materials for further research.

Northern Powder River Basin project completed

The WSGS in conjunction with the Wyoming Water Resource Division of the Wyoming Geographic Information Science Center (WyGISC) and the USGS Water Resources Division has released the Northern Wyoming Powder River Basin Water Quality Project to the public via the Internet. This project was more than two years in the making and was funded through the Wyoming Water Development Commission. The Geologic Hazards, Geologic Mapping,

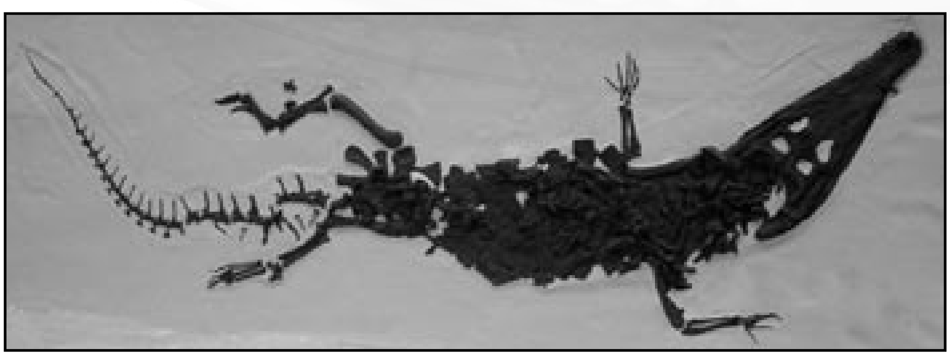

Figure 1. Resin cast of 13-foot long crocodile from the Green River Formation, Wyoming. Photograph by Jaime R. Moulton, February, 2004.

Figure 2. Resin cast of 6-foot long turtle from the Green River Formation, Wyoming. Photograph by Jaime R. Moulton, February, 2004.

Oil and Gas, and Coal sections at the WSGS were all involved in the project.

The purpose of this project is to make water quality data available as it relates to coal and non-coal aquifers within the Tertiary Wasatch (Eocene) and Fort Union (Paleocene) formations with regard to coalbed methane (CBM) development. Data representing both ground and surface water chemistry covering a range of constituents will be available.

The water quality model is supported by a geologic framework ("model") developed from both surface geology and geophysical well data that was collected from over 6000 oil, gas, and CBM wells. The initial coal correlation data was purchased from Goolsby and Associates of Casper and modified by the WSGS. The final PRB project is designed so that lithostratigraphic columns as well as cross sections may be generated anywhere within the project area.

The geologic model, which was developed using ESRI's ArcINFO®, GIS 3D®, and Spatial Analyst® software, includes a detailed bedrock geologic map, coal seam outcrops, 32 unique coal seam horizons, and four geologic formation tops (Late Cretaceous Bearpaw\Pierre Shale, Fox Hills Formation, and Lance Formation, and the Paleocene Fort Union Formation).

This project represents a snapshot in time with respect to both coal correlations as well as collected water quality data. Anyone with access to the Internet will be able to utilize this interactive, menu-driven Internet-based Map Server (IMS). The WSGS and the Wyoming Water Resource Data System will have links to the IMS from each of their web sites. To access the site directly, go to www.wrds.uwyo.edu/ and click on "Online Data," go to "Cooperative Projects with the Wyoming State Geological Survey" and click on "Northern Powder River Basin Water Quality Project."

Oil and Gas Update

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Wyoming producers received higher prices for both oil and natural gas in the first three quarters of 2003 than they received during the same period in 2002. Average oil prices for the first nine months of 2003 were up $5.33 per barrel over average prices for the first nine months of 2002. Natural gas prices for the first nine months of 2003 were $2.48 per thousand cubic feet (MCF) higher than for the same period in 2002. The decline in oil production was 3.9%, while natural gas production increased 5.1% during the first three quarters of 2003. Coalbed methane (CBM) production from the Powder River Basin (PRB) accounted for 257.8 billion cubic feet (BCF), which was 19.2% of Wyoming's natural gas production. Gas production from Jonah Field and from wells on the Pinedale anticline accounted for 254.7 BCF, or 19.0% of Wyoming's total production.

The Energy Information Administration (EIA) reported that Wyoming's proved reserves of natural gas, crude oil, and natural gas liquids all increased from last year. Wyoming gained over 2.1 trillion cubic feet (TCF) of proved reserves of natural gas over last year and gained 6.3 TCF of proved reserves over the past three years, despite production of over 4.8 TCF over the three-year period. As of the beginning of 2003, Wyoming ranked second among the states in dry natural gas reserves, third in natural gas liquids, and sixth in crude oil.

The August federal lease sale brought in over $3.3 million. The high per-acre bid was $675 for a 1320-acre lease. The second high per-acre bid was $625 for a 640-acre tract. The sale generated $3.4 million and the average per-acre bid was $27.63. There were 13 parcels at this sale that received a bid of $50 or more per acre.

The number of applications for permit to drill in the first three quarters of 2003 remained healthy. The Wyoming Oil and Gas Conservation Commission (WOGCC) permitted 11 less seismic projects in the first nine months of 2003 than for the same period in 2002. The number of conventional miles permitted in three quarters of 2003 was 1577 lower than in three quarters of 2002, but the square miles total was 559 more. The average daily rig count for the third quarter of 2003 was 64, which is 21 more than for the third quarter of 2002.

Prices and production

Prices paid to Wyoming oil producers during the first nine months of 2003 averaged $26.80 per barrel (**Table 3**). This average price is $5.33 higher than for the comparable period in 2002. Over the last four years, the average monthly price for a barrel of Wyoming crude oil has been over $20 for all but the last three months of 2001 and the first two months of 2002 (**Table 3**). With one exception, oil prices in the last four years have been higher than the previous 13 years (**Figure 3**) and are at the levels they were in the early 1980s. Our predicted average price for oil in 2003 was $25.75 per barrel (**Table 1**), but preliminary data indicate that this price may be about $1.00 per barrel too low (**Table 3**).

Oil production reported by the WOGCC for the first nine months of 2003 was 39.4 million barrels (**Table 4**). This production decreased 3.9% from the first three quarters of 2002 and by year's end, production is expected to be 52.5 million barrels (**Table 1**). See *Wyoming Geo-notes No. 78*, November, 2003 for a discussion of our latest projections for both prices and production of Wyoming oil.

Table 3. Monthly average price of a barrel of oil produced in Wyoming (1999 through December, 2003).

	1999		2000		2001		2002		2003	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	$9.30	$9.30	$24.01	$24.01	$24.62	$24.62	$15.70	$15.70	$28.02	$28.02
February	$9.09	$9.20	$26.48	$25.25	$24.82	$24.72	$16.63	$16.17	$31.00	$29.51
March	$11.77	$10.05	$27.24	$25.91	$22.71	$24.05	$20.64	$17.66	$28.92	$29.31
April	$14.34	$11.13	$22.92	$25.16	$22.85	$23.75	$22.63	$18.90	$24.50	$28.11
May	$15.16	$11.93	$26.06	$25.34	$23.68	$23.74	$22.86	$19.69	$24.51	$27.39
June	$15.36	$12.50	$28.31	$25.84	$22.99	$23.61	$21.71	$20.03	$26.55	$27.25
July	$17.39	$13.20	$27.12	$26.02	$22.55	$23.46	$23.29	$20.49	$26.37	$27.12
August	$18.43	$13.86	$28.18	$26.29	$23.67	$23.49	$24.27	$20.97	$27.20	$27.13
September	$20.97	$14.65	$30.22	$26.73	$22.02	$23.32	$25.47	$21.47	$24.16	$26.80
October	$20.01	$15.18	$28.75	$26.93	$17.71	$22.76	$24.27	$21.75	$25.71	$26.69
November	$22.20	$15.82	$29.63	$27.17	$16.44	$22.19	$22.66	$21.83	**$26.50**	**$26.68**
December	$23.22	$16.44	$23.60	$26.88	$14.86	$21.58	$24.85	$22.08	**$27.75**	**$26.77**
Average yearly price		**$16.44**		**$26.88**		**$21.58**		**$22.08**		**$26.77**

All averages are derived from published monthly reports by the Energy Information Administration, except that averages in bold print in 2003 are estimated from various unpublished bulletins listing posted prices. *Wyoming State Geological Survey, Oil and Gas Section, February, 2004.*

Table 4. Monthly oil production from Wyoming in barrels (1999 through October, 2003)

	1999		2000		2001		2002		2003	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	5,333,257	5,333,257	5,187,557	5,187,557	5,003,766	5,003,766	4,711,532	4,711,532	4,719,048	4,719,048
February	4,744,527	10,077,784	4,873,042	10,060,599	4,495,136	9,498,902	4,238,372	8,949,904	4,129,307	8,848,355
March	5,297,674	15,375,458	5,213,721	15,274,320	4,972,168	14,471,070	4,629,468	13,579,372	4,465,050	13,313,405
April	5,065,591	20,441,049	5,014,266	20,288,586	4,804,531	19,275,601	4,565,445	18,144,817	4,338,347	17,651,752
May	5,200,031	25,641,080	5,205,848	25,494,434	4,933,201	24,208,802	4,687,127	22,831,944	4,462,093	22,113,845
June	5,000,039	30,641,119	5,005,008	30,499,442	4,678,672	28,887,474	4,495,524	27,327,468	4,245,164	26,359,009
July	5,164,705	35,805,824	5,083,393	35,582,835	4,854,173	33,741,647	4,595,080	31,922,548	4,412,186	30,771,195
August	5,190,052	40,995,876	5,108,431	40,691,266	4,768,811	38,510,458	4,626,308	36,548,856	4,363,779	35,134,974
September	5,081,384	46,077,260	4,990,825	45,682,091	4,726,876	43,237,334	4,492,324	41,041,180	4,305,817	39,440,791
October	5,163,165	51,240,425	5,165,311	50,847,402	4,834,294	48,071,628	4,623,348	45,664,528	4,376,164	43,816,955
November	5,010,985	56,251,410	4,884,659	55,732,061	4,655,985	52,727,613	4,456,006	50,120,534		
December	5,090,959	61,342,369	4,987,669	60,719,730	4,763,863	57,491,476	4,596,150	54,716,684		
Total Barrels Reported [1]		**61,342,369**		**60,719,730**		**57,491,476**		**54,716,684**		

[1]Monthly production reports are from Wyoming Oil and Gas Conservation Commission. *Wyoming State Geological Survey, Oil and Gas Section, February, 2004.*

Spot prices for natural gas at Opal, Wyoming averaged $4.36 per MCF during the first nine months of 2003. This is $2.48 per MCF higher than the average price for the same period in 2002 (**Table 5** and **Figure 4**). Spot prices for natural gas have held at relatively high levels through the first three quarters of the year because storage levels at the end of last year's heating season were extremely low and injection of natural gas to refill depleted storage continued throughout the summer months. The completion of new pipeline capacity out of Wyoming decreased the price differential between natural gas from Wyoming and natural gas from other areas of the U.S. and had a positive effect on the average price of Wyoming natural gas. By year's end, Wyoming's natural gas price of $4.41 per MCF had exceeded our forecast price by $0.21 per MCF (see *Wyoming Geo-notes No. 78*, November, 2003).

Natural gas production in Wyoming for the first nine months of 2003 was almost 1342 BCF according to production figures from the WOGCC. This production is up 5.1% from the comparable period in 2002 (**Table 6**) and production is

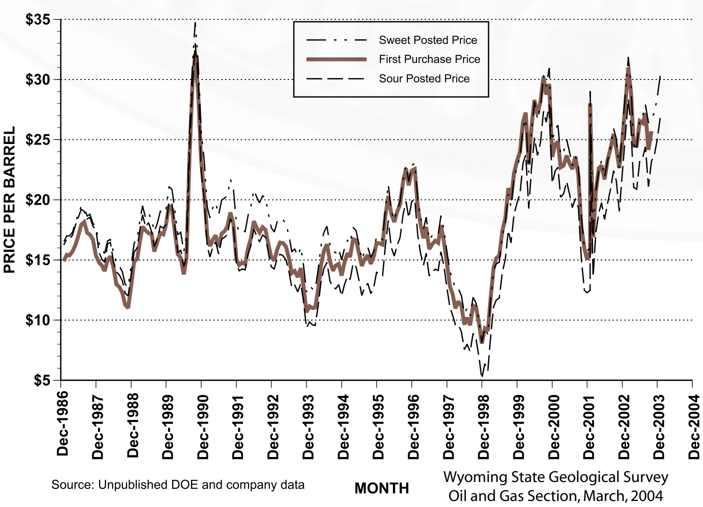

Figure 3. Wyoming posted sweet and sour crude oil prices and first purchase prices, averaged by month (January, 1987 through October, 2004).

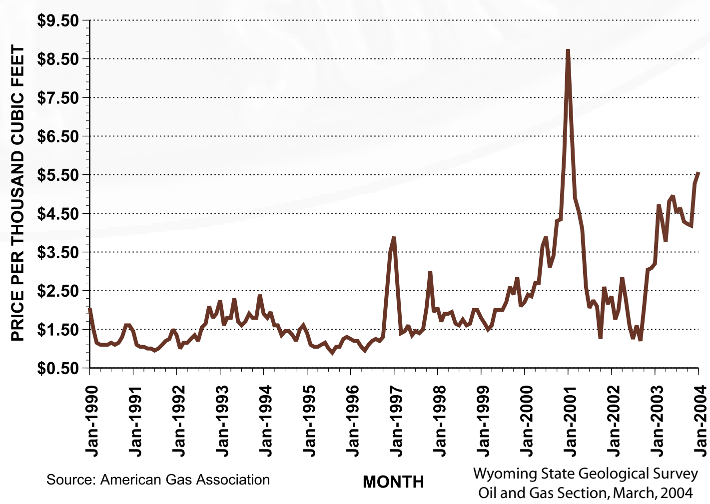

Figure 4. Spot sale prices for methane at Opal, Wyoming, averaged by month (January, 1990 through December, 2003).

Table 5. Monthly average spot sale price for a thousand cubic feet (MCF) of natural gas at Opal, Wyoming (1999 through December, 2003).

	1999		2000		2001		2002		2003	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	$1.80	$1.80	$2.20	$2.20	$8.75	$8.75	$2.35	$2.35	$3.20	$3.20
February	$1.65	$1.73	$2.40	$2.30	$6.60	$7.68	$1.75	$2.05	$4.73	$3.97
March	$1.50	$1.65	$2.35	$2.32	$4.90	$6.75	$2.00	$2.03	$4.34	$4.09
April	$1.60	$1.64	$2.70	$2.41	$4.55	$6.20	$2.85	$2.24	$3.76	$4.01
May	$2.00	$1.71	$2.70	$2.47	$4.10	$5.78	$2.30	$2.25	$4.81	$4.17
June	$2.00	$1.76	$3.65	$2.67	$2.60	$5.25	$1.60	$2.14	$4.96	$4.30
July	$2.00	$1.79	$3.90	$2.84	$2.05	$4.79	$1.25	$2.01	$4.52	$4.33
August	$2.20	$1.84	$3.10	$2.88	$2.25	$4.48	$1.60	$1.96	$4.65	$4.37
September	$2.60	$1.93	$3.40	$2.93	$2.10	$4.21	$1.20	$1.88	$4.29	$4.36
October	$2.40	$1.98	$4.30	$3.07	$1.25	$3.92	$2.04	$1.89	$4.23	$4.35
November	$2.85	$2.05	$4.35	$3.19	$2.60	$3.80	$3.04	$2.00	$4.18	$4.33
December	$2.10	$2.06	$6.00	$3.42	$2.15	$3.66	$3.08	$2.09	$5.27	$4.41
Average Yearly Price		**$2.06**		**$3.42**		**$3.66**		**$2.09**		**$4.41**

Source: American Gas Association's monthly reports. Starting in October, 2002, averages calculated from weekly prices posted on Enerfax web site. *Wyoming State Geological Survey, Oil and Gas Section, February, 2004.*

Table 6. Monthly natural gas production from Wyoming in thousands of cubic feet (MCF) (1998 through October, 2003).

	1999		2000		2001		2002		2003	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	108,524,793	108,524,793	122,320,888	122,078,095	135,998,574	135,998,574	143,510,891	143,510,891	160,828,662	160,828,662
February	94,288,888	202,813,681	112,851,735	235,172,623	123,506,503	259,505,077	132,981,761	276,492,652	143,894,904	304,723,566
March	111,012,987	313,826,668	121,287,580	356,460,203	139,126,687	398,631,764	143,707,799	420,200,451	158,362,132	463,085,698
April	102,363,550	416,190,218	118,886,204	475,346,407	132,684,058	531,315,822	141,016,463	561,216,914	149,921,731	613,007,429
May	104,746,697	520,936,915	118,631,057	593,977,464	138,214,926	669,530,748	146,950,768	708,167,682	141,926,937	754,934,366
June	102,717,295	623,654,210	117,033,775	711,011,239	128,145,994	797,676,742	141,386,350	849,554,032	145,620,502	900,554,868
July	106,733,493	730,387,703	120,838,202	831,849,441	131,752,355	929,429,097	145,796,954	995,350,986	148,946,379	1,049,501,247
August	107,536,099	837,923,802	122,698,001	954,547,442	132,847,188	1,062,276,285	139,407,056	1,134,758,042	149,009,789	1,198,511,036
September	108,200,542	946,124,344	120,166,494	1,074,713,936	131,334,584	1,193,610,869	142,448,905	1,277,206,947	143,468,209	1,341,979,245
October	118,545,893	1,064,670,237	127,682,448	1,202,396,384	137,507,181	1,331,118,050	151,247,991	1,428,454,938	151,923,928	1,493,903,173
November	110,904,046	1,175,574,283	123,108,333	1,325,504,717	136,878,261	1,467,996,311	155,751,286	1,584,206,224		
December	119,648,215	1,295,222,498	131,474,722	1,456,979,439	144,790,631	1,612,786,942	162,039,833	1,746,246,057		
Total MCF Reported [1]		**1,295,222,498**		**1,456,979,439**		**1,612,786,942**		**1,746,246,057**		

[1] Monthly production reports are from Wyoming Oil and Gas Conservation Commission. *Wyoming State Geological Survey, Oil and Gas Section, February, 2004.*

expected to be 1800 BCF by year's end (**Table 1**). Increased natural gas production for the first three quarters of 2003 from Jonah Field and from wells on the Pinedale anticline accounted for 254.7 BCF, or about 19% of Wyoming's total production. See *Wyoming Geo-notes No. 78*, November, 2003 for a complete discussion of our latest natural gas forecasts.

CBM production from the PRB accounted for 257.8 BCF of the total for the first three quarters of 2003 and was 19.2% of Wyoming's natural gas production. CBM production rates are once again increasing after decreasing for most of the first six months. The average daily production for September was 977 million cubic feet of gas (MMCF) per day. The drilling of new wells in the PRB is still impeded by the slow pace of approval for drilling permits by the U.S. Bureau of Land Management (BLM), but increased production from the Big George coal bed is partially offsetting this impediment. See the **Coalbed Methane Update** for more news and statistics.

Reports and projects

The Energy Information Administration (EIA) released its new reserve estimates for natural gas, crude oil, and natural gas liquids in the U.S. Among the top ten states at the end of 2002, Wyoming ranked second in dry natural gas reserves, third in natural gas liquids, and sixth in crude oil reserves (**Table 7**). Wyoming had the largest increase of any state in proved reserves of dry natural gas with over 2.1 TCF of gas added (**Table 8**). Most of the increase came from development drilling at Jonah Field, Pinedale anticline, and Madden Field. This is the third year in a row that Wyoming has added more dry natural gas reserves than any other state. Over that three-year period, Wyoming has added 6.3 TCF in dry natural gas reserves despite production of 4.8 TCF.

Wyoming had the largest increase of any state in proved reserves of dry natural gas with over 2.1 TCF of gas added.

Wyoming's proved reserves of crude oil were revised upward and Wyoming moved from seventh to sixth place among the states (**Table 7**). Two enhanced oil projects by Anadarko Petroleum that began late in 2003 should help slow down or possibly reverse the decline in reserves that has been the trend over the last 20 years (**Table 8**). The EIA also revised Wyoming's proved reserves of natural gas liquids upward (**Table 8**), but Wyoming remained in third place among the states (**Table 7**).

The U.S. Department of the Interior, Minerals Management Service (MMS) distributed $1,019,980,770 to states during Federal Fiscal Year 2003, which ended in September, 2003. The distribution was the states' cumulative share of revenues collected from mineral production on federal lands located within their

Table 7. Wyoming's ranking in proved reserves of crude oil (billions of barrels), dry natural gas (trillions of cubic feet), and natural gas liquids (billions of barrels) at the beginning of 2003.

State	Crude Oil	State	Dry Natural Gas	State	Natural Gas Liquids
Texas	5.015	Texas	44.297	Texas	2.711
Alaska	4.678	**Wyoming**	**20.527**	New Mexico	0.838
California	3.633	New Mexico	17.320	**Wyoming**	**0.780**
New Mexico	0.710	Oklahoma	14.886	Oklahoma	0.695
Oklahoma	0.598	Colorado	13.88	Alaska	0.405
Wyoming	**0.524**	Louisiana	8.960	Colorado	0.396
Louisiana	0.501	Alaska	8.468	Louisiana	0.323
North Dakota	0.342	Kansas	4.983	Kansas	0.263
Montana	0.288	Utah	4.135	Utah	0.158
Utah	0.241	Alabama	3.884	California	0.095

Source: Energy Information Administration, 2003. *Wyoming State Geological Survey, Oil and Gas Section, February, 2004.*

borders. Wyoming led all states, receiving $467 million as its share or 45.8% of the total. New Mexico was second with $297 million or 29.1% of the total. Fiscal Year 2002 payments to states totaled only $716.3 million. Higher natural gas prices are mainly responsible for the increased revenues in Fiscal Year 2003.

The new Grasslands Pipeline, owned by Williston Basin Interstate Pipeline, (see *Wyoming Geo-notes No. 78*, November, 2003, p. 7) became available for natural gas transmission service on December 23, 2003. Pipeline construction began in the middle of August. Firm pipeline volumes could increase to as much as 200 MMCF of gas per day, depending on market demand.

The proposal also includes a minimum of 64 well pads per section, well spacing that varies from 5 to 20 acres, drilling at a rate of 250 wells per year, exploration activity in previously unexplored formations. . .

Table 8. Comparison of Wyoming's proved reserves of crude oil (billions of barrels), dry natural gas (trillions of cubic feet), and natural gas liquids (billions of barrels) for the years 1980 through 2002.

Date	Crude Oil	Dry Natural Gas	Natural Gas Liquids[1]
1980	0.928	9.100	0.239
1981	0.840	9.307	0.269
1982	0.856	9.758	0.477
1983	0.957	10.227	0.552
1984	0.954	10.482	0.602
1985	0.951	10.617	0.664
1986	0.849	9.756	0.665
1987	0.854	10.023	0.647
1988	0.825	10.308	0.808
1989	0.815	10.744	0.627
1990	0.794	9.944	0.568
1991	0.757	9.941	0.524
1992	0.689	10.826	0.462
1993	0.624	10.933	0.420
1994	0.565	10.789	0.395
1995	0.605	12.166	0.415
1996	0.603	12.320	0.505
1997	0.627	13.562	0.600
1998	0.547	13.650	0.535
1999	0.590	14.226	0.515
2000	0.561	16.158	0.750
2001	0.489	18.398	0.710
2002	0.524	20.527	0.780

[1]Estimated from Energy Information Administration figures. Source: Energy Information Administration, 2004. *Wyoming State Geological Survey, Oil and Gas Section, February, 2004.*

Southwestern Wyoming's Jonah Field could have up to 3100 new wells under a revised development proposal submitted to the BLM by EnCana Oil & Gas (USA). The proposal also includes a minimum of 64 well pads per section, well spacing that varies from 5 to 20 acres, drilling at a rate of 250 wells per year, exploration activity in previously unexplored formations, and the establishment of a Cumulative Impacts Mitigation Fund to implement offsite mitigation opportunities. Jonah is the second largest field in yearly production behind CBM production in the PRB Coal Field and should produce about 240 BCF of natural gas in 2003. The field will top 1 TCF of cumulative production by the fourth month of 2004 and should eclipse CBM from the PRB as the largest producing field in Wyoming in terms of yearly production. Estimates of Jonah's recoverable resources of natural gas vary from 4 to 10 TCF.

Veritas DGC Land Inc. has received approval to complete a 3-D seismic project in the Hay Reservoir area of southwestern Wyoming. The BLM issued a Decision Record and Finding of No Significant Impact for the Great Divide Basin project, which will cover about 279 square miles. Veritas plans to use 62 receiver lines totaling about 260 linear miles aligned in a northeast-southwest direction and spaced 1540 feet apart.

The BLM granted Questar Exploration & Production Company's request to conduct winter-long drilling on the Mesa area of Pinedale anticline. The operations will be from a single location in designated crucial winter range for mule deer. The 8-32 Stewart Point pad is about 6 miles southwest of Pinedale. Questar plans to drill eight wells from this pad and four of those wells could be drilled in the 2003-2004 winter season. Each well will be drilled directionally and will take 50 to 60 days to drill. The surface disturbance associated with this operation is just over 13 acres compared to 49 acres if each of the eight wells required its own pad.

Lease sales

Leasing activity at the August BLM sale was scattered throughout the state (**Figure 5**). The high per-acre bid of $675 was made by Contex Energy for a 1320-acre lease that covers parts of sections 25, 26 and 27, T37N, R91W (**location A, Figure 5**). The lease is about 4.5 miles west-southwest of Kanson Draw Field, an inactive Lance gas pool. The second high per-acre bid of $625 was made by Ann Trujillo for a 640-acre tract that covers section 12, T22N, R96W (**location B, Figure 5**). The lease offsets Lewis Shale gas production in Red Desert Field. The sale generated $3,357,650 and the average per-acre bid was $27.63 (**Table 9**). There were 13 parcels at this sale that received a bid of $50 or more per acre.

Table 9. Federal and state competitive oil and gas lease sales in Wyoming (1999 through August, 2003).

Federal Sales (U.S. 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
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
October	$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	**$26,501,672**	**1,069**	**945**	**1,060,674**	**929,674**	**$28.51**	**$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**	**1,183**	**1,055**	**1,058,204**	**898,612**	**$35.01**	**$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**	**1,023**	**933**	**1,103,745**	**973,282**	**$34.92**	**$1,475.00**
2002							
February	$5,137,024	219	164	271,248	177,117	$29.00	$345.00
April	$2,969,094	142	127	136,864	117,852	$25.19	$375.00
June	$1,183,222	91	63	82,958	55,808	$21.20	$185.00
August	$858,686	124	89	111,462	88,719	$9.68	$205.00
October	$578,597	117	86	122,962	72,039	$8.03	$46.00
December	$866,561	111	95	86,139	73,237	$11.83	$165.00
Total	**$11,593,184**	**804**	**624**	**811,633**	**584,772**	**$19.83**	**$375.00**
2003							
February	$170,647	37	27	28,836	19,746	$8.64	$56.00
April	$1,455,295	98	71	49,521	33,304	$43.70	$310.00
June	$1,729,660	63	54	46,412	40,177	$43.05	$360.00
August	$3,357,650	177	104	233,189	121,515	$27.63	$675.00
October							
December							
Total	**$6,713,252**	**375**	**256**	**357,958**	**214,742**	**$31.26**	**$675.00**

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
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**	**$83.86**	**$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**	**1,199**	**796**	**475,090**	**295,915**	**$86.27**	**$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**	**$66.13**	**$650.00**
2002							
April	$465,104	200	90	74,321	35,084	$13.26	$105.00
June	$517,143	200	124	74,608	46,481	$11.04	$525.00
October	$1,222,823	198	133	70,800	47,436	$25.77	$480.00
Total	**$2,205,070**	**598**	**347**	**219,729**	**129,001**	**$50.07**	**$525.00**
2003							
April	$812,916	200	92	79,290	30,152	$26.96	$350.00
June	$583,950	200	121	76,433	43,966	$13.28	$575.00
October							
Total	**$1,396,866**	**400**	**213**	**155,723**	**74,118**	**$40.24**	**$575.00**

Sources: Wyoming Office of Sta
Wyoming State Geological Survey, Oil and Gas Section, February, 2004.

Permitting and drilling

The WOGCC approved 5298 Applications for Permit to Drill (APDs) in the first nine months of 2003 (**Table 10**), which is 524 more than in the first three quarters of 2002. The total for the first nine months of 2003 is more than approvals for the full years of 1995 through 1998. Campbell County again led with 37.6% of the total APDs that were approved; Sheridan and Johnson counties combined for another 36.6% of the total. Nearly all of the approved APDs in these three counties were for CBM tests. The slowdown in drilling permits for Campbell County in 2002 and the first three quarters of 2003 when compared to 2001 is due to a lack of CBM drilling locations on federal land. The increase in approved drilling permits for Sweetwater and Sublette counties since 2000 (**Table 10**) is due to companies emphasizing the development and exploration for natural gas reserves in southwestern Wyoming in lieu of oil reserves in the Bighorn and Powder River basins.

The higher prices for natural gas, and to a lesser extent, higher prices for crude oil, are responsible for the improved rig count.

The WOGCC permitted 22 seismic projects in the first three quarters of 2003. The number of permits is 11 less than for the first three quarters of 2002. The number of conventional miles permitted in three quarters of 2003 was 1577 lower than for the same period in 2002, but the square miles total is 559 more (**Table 11**). Geophysical activity is a good indicator of future exploration and production drilling.

The average daily rig count for the third quarter of 2003 was 64. This average is 21 more than for the third quarter of 2002. The rig count does not include rigs drilling for CBM. The higher prices for natural gas, and to a lesser extent, higher prices for crude oil, are responsible for the improved rig count. Average monthly prices for natural gas have been above $3.00 per MCF since November, 2002 (**Table 5**) and average monthly oil prices have been above $20.00 per barrel since March, 2002 (**Table 3**). **Figure 6** shows the Wyoming daily rig count averaged by month and by year.

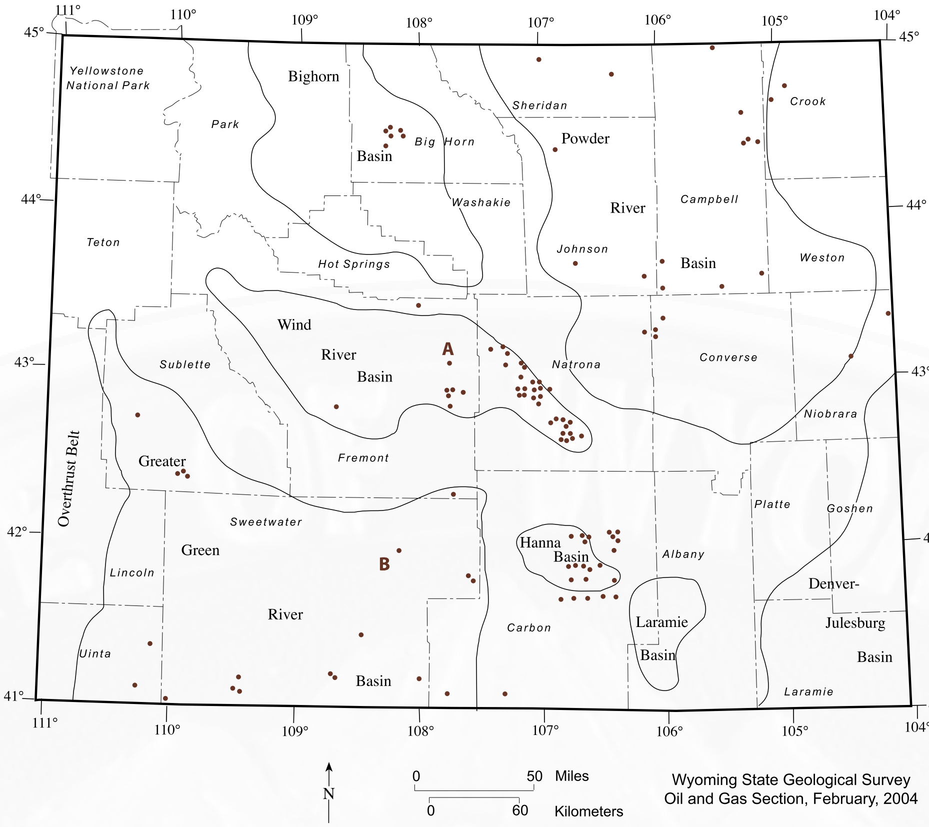

Figure 5. Locations of federal oil and gas tracts leased by the U.S. Bureau of Land Management at its August, 2003 sale. Locations are approximate and may represent more than one tract.

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 12** reports the most significant activities exclusive of CBM (see the **Coalbed Methane Update** for development in the industry) during the first three quarters of 2003. The numbers correspond to locations on **Figure 7**.

Table 10. Number of Applications for Permit to Drill (APDs) approved by the Wyoming Oil and Gas Conservation Commission (1997 through September, 2003).

County	1997 APDs	1998 APDs	1999 APDs	2000 APDs	2001 APDs	2002 APDs	2003 APDs
Albany	0	0	0	0	1	1	1
Big Horn	59	13	6	11	23	8	4
Campbell	941	1586	4461	5580	6204	2793	1990
Carbon	84	96	127	174	261	198	190
Converse	16	6	19	70	25	43	41
Crook	26	29	30	47	20	13	48
Fremont	58	76	67	136	149	62	94
Goshen	0	0	0	0	0	1	0
Hot Springs	42	1	8	6	2	9	3
Johnson	6	49	304	769	805	799	766
Laramie	3	2	0	2	3	3	1
Lincoln	122	105	51	70	87	51	51
Natrona	59	36	51	53	45	49	68
Niobrara	8	8	5	18	15	10	14
Park	25	11	12	18	45	23	46
Platte	0	0	0	0	0	0	0
Sheridan	2	35	416	891	1811	1531	1172
Sublette	179	230	189	338	435	428	351
Sweetwater	210	181	124	335	534	379	434
Teton	0	0	0	0	0	0	0
Uinta	27	26	26	53	35	16	12
Washakie	36	9	0	7	10	1	0
Weston	5	6	4	20	7	2	12
Totals	**1908**	**2505**	**5900**	**8598**	**10,517**	**6420**	**5298**

Source: All data are from the Wyoming Oil and Gas Conservation Commission. *Wyoming State Geological Survey, Oil and Gas Section, February, 2004.*

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Energy Information Administration, 2003, U.S. crude oil, natural gas, and natural gas liquids reserves: 2002 Annual Report: Washington, D.C., 170 p.

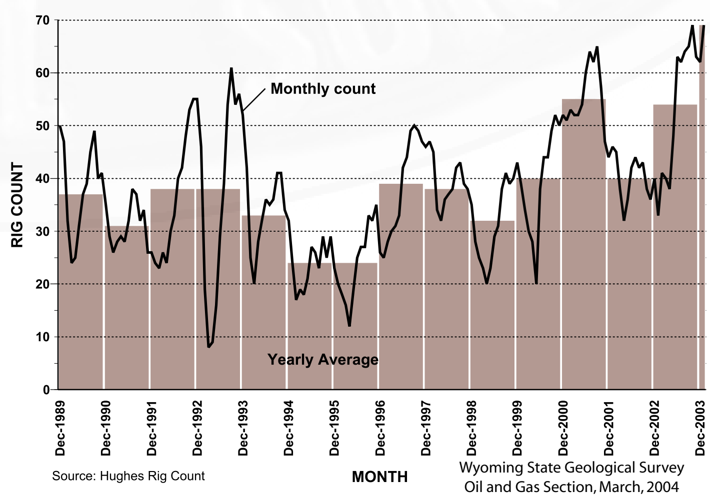

Figure 6. Wyoming daily rig count, exclusive of coalbed methane rigs, averaged by month and year (December, 1989 through January, 2004).

Table 11. Number of seismic projects and miles permitted by the Wyoming Oil and Gas Conservation Commission (1999 through September, 2003).

County	2000 Permits	2000 Conventional Miles	2000 3-D Square Miles	2001 Permits	2001 Conventional Miles	2001 3-D Square Miles	2002 Permits	2002 Conventional Miles	2002 3-D Square Miles	2003 Permits	2003 Conventional Miles	2003 3-D Square Miles
Albany	0	0	0	0	0	0	1	6	0	0	0	0
Big Horn	1	387	0	1	0	4	0	0	0	0	0	0
Campbell	14	64	132	5	38	3	10	49	3	3	8	0
Carbon	0	0	0	1	500	0	4	419	3	1	0	55
Converse	1	15	0	0	0	0	2	6	47	1	0	75
Crook	7	16	22	4	32	0	1	0	2	3	46	0
Fremont	4	25	116	2	70	15	1	160	0	4	12	717
Goshen	0	0	0	0	0	0	0	0	0	0	0	0
Hot Springs	0	0	0	0	0	0	0	0	0	0	0	0
Johnson	4	35	0	2	4	4	1	16	0	1	25	0
Laramie	0	0	0	0	0	0	1	0	18	0	0	0
Lincoln	0	0	0	1	0	25	0	0	0	0	0	0
Natrona	5	36	135	2	19	63	4	11	72	0	0	0
Niobrara	1	0	25	1	0	16	3	3	52	2	0	42
Park	1	13	0	4	21	20	0	0	0	1	0	6
Platte	0	0	0	0	0	0	0	0	0	0	0	0
Sheridan	0	0	0	2	0	81	0	0	0	0	0	0
Sublette	4	77	44	10	261	374	1	464	0	2	0	238
Sweetwater	13	54	1004	11	129	802	7	348	485	2	1	8
Teton	0	0	0	0	0	0	0	0	0	0	0	0
Uinta	0	0	0	1	259	0	2	196	0	1	0	47
Washakie	0	0	0	0	0	0	1	21	0	1	4	0
Weston	0	0	0	0	0	0	0	0	0	0	0	0
Totals	**55**	**722**	**1478**	**47**	**1333**	**1407**	**39**	**1699**	**682**	**22**	**96**	**1188**

Source: All data are from the Wyoming Oil and Gas Conservation Commission. *Wyoming State Geological Survey, Oil and Gas Section, February, 2004.*

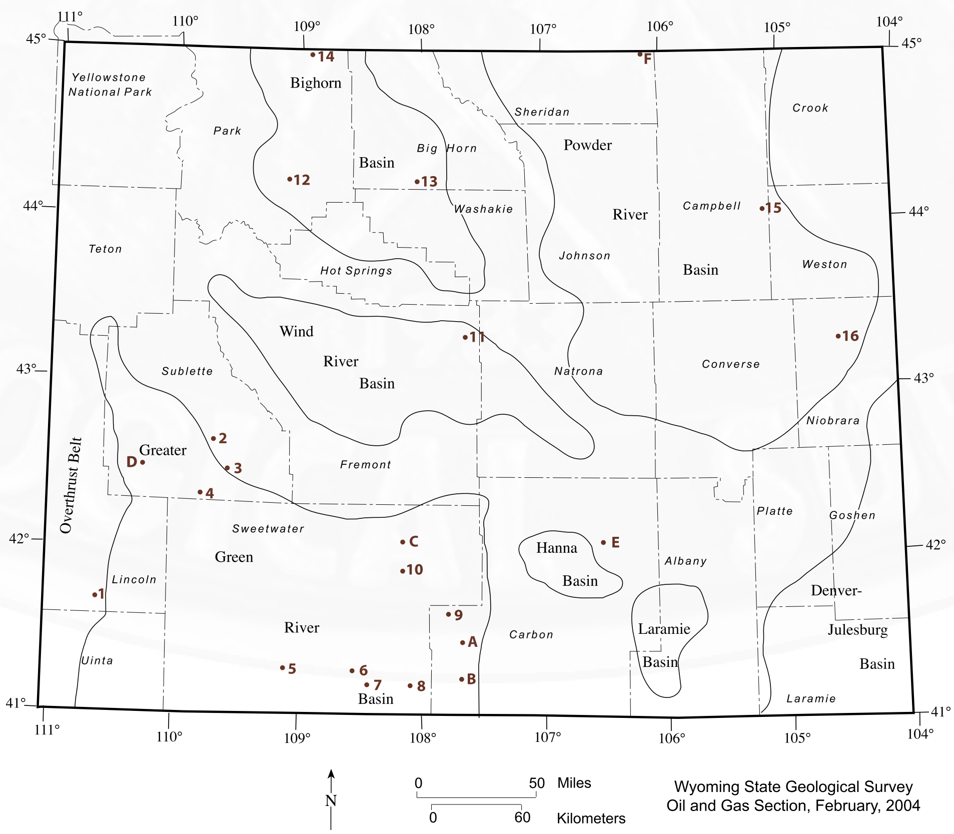

Figure 7. Oil and gas exploration and development activities in Wyoming during the third quarter of 2003. Numbers are those used in Table 12**. Letters indicate coalbed methane developments described in the** Coalbed Methane Update**. Locations are approximate and may represent more than one well location or project.**

Table 12. Significant exploration and development wells in Wyoming, third quarter of 2003. Number corresponds to location on Figure 7.

	Company name	Well name/number	Location	Formation tested	Depth(s) interval(s) tested	Tested prod. (per day)	Remarks
1	Sampson Resources	11-16 Bear River Divide-State	NW SW sec16, T20N, R117W	Adaville Fm.	undisclosed	1.0 MMCF 11 BBL cond 6 BBL H_2O	Wildcat discovery, no other production from Adaville in the vicinity. Tested production is actual average production for first three months.
2	Ultra Resources	13-11 Warbonnet	SW SW sec 11, T30N, R108W	Lance Fm.	18 intervals 7994-13,479	8.0 MMCF 144 BBL cond 666 BBL H_2O	New producer in Warbonnet area of Pinedale anticline
	Ultra Resources	1-33 Mesa	NE NE sec 33, T32N, R109W	Lance Fm. Mesaverde Fm.	17 intervals 8423-13,810	10.0 MCF	New Pinedale anticline producer
	Ultra Resources	10-33 Mesa	NW SE sec 33, T32N, R109W	Lance Fm. Mesaverde Fm.	18 intervals 8282-13,748	19.9 MMCF 225 BBL cond 933 BBL H_2O	New Pinedale anticline producer
	Ultra Resources	7-34 Mesa	SW NE sec 34, T32N, R109W	Lance Fm.	21 intervals 8065-13,757	10.5 MMCF 80 BBL cond 297 BBL H_2O	New Pinedale anticline producer
	Shell Rocky Mountain Production	12-34 Mesa	NW SW sec 34, T32N, R109W	Lance Fm. Mesaverde Fm.	8156-12,554	13.8 MMCF 87 BBL cond 105 BBL H_2O	New Pinedale anticline producer
	Shell Rocky Mountain Production	1-11D Vible	SE NE sec 11, T31N, R109W	Lance Fm. Mesaverde Fm.	several intervals 7477-12,646	9.3 MMCF 35 BBL cond 144 BBL H_2O	New Pinedale anticline producer
3	BP America Production	15-23 Antelope	SW SE sec 23, T29N, R107W	Lance Fm.	nine intervals 10,604-12,847	1.4 MMCF 6 BBL cond 110 BBL H_2O	Wildcat discovery, about three miles east of Jonah Field
4	McMurry Oil	6-1 Holmes-Federal	SE NW sec 1, T27N, R109W	Lance Fm.	three intervals 7655-8400	3.7 MMCF	Offset to 1999 Lance discovery, about three miles southwest of production at Jonah Field
	McMurry Oil	4-1 Holmes-Federal	NW NW sec 1, T27N, R109W	Lance Fm.	three intervals 7572-8633	1.8 MMCF	Offset to 1999 Lance discovery, about three miles southwest of production at Jonah Field
	McMurry Oil	3-1 Holmes-Federal	NE NW sec 1, T27N, R109W	Lance Fm.	7981-8235 8288-8411	1.7 MMCF	Offset to 1999 Lance discovery, about three miles southwest of production at Jonah Field
5	Wexpro	22 South Baxter Unit	NW SW sec 5, T15N, R104W	Dakota Ss.	3570-3602	12.0 MMCF	Wildcat discovery, over one half mile from abandoned Lakota and Dakota production at Little Worm Creek Field
6	Yates Petroleum	1 Legend-Federal	NW NE sec 22, T15N, R99W	Lewis Sh. Almond Fm.	several intervals 12,687-14,265	1.0 MMCF 27 BBL H_2O	Wildcat discovery
7	Yates Petroleum	1 Wrangler-Federal	SW SW sec 19, T14N, R98W	Fort Union Fm.	12,042-12,059	426 MCF	Wildcat discovery
8	EOG Resources	22-18 Cepo-Lewis	SW SE sec 18, T14N, R95W	Lewis Sh.	undisclosed	4.1 MMCF	New producer in Cepo Field
9	BP America Production	25-2 High Point	NE NE sec 25, T19N, R92W	Lewis Sh.		2.0 MMCF 220 BBL cond 84 BBL H_2O	New producer in the area of Fillmore, Creston, and Echo Springs East fields
	BP America Production	23-1 High Point	SE SW sec 23, T19N, R92W	Lewis Sh. Mesaverde Gp.	8026-8078 8634-8936	2.1 MMCF 122 BBL cond 102 BBL H_2O	New producer in the area of Fillmore, Creston, and Echo Springs East fields
	Yates Petroleum	1 Seaverson	SW NE sec 24, T19N, R92W	Lewis Sh.	7821-7903	1.3 MMCF 162 BBl cond 90 BBL H_2O	New producer in the area of Fillmore, Creston, and Echo Springs East fields
10	BP America Production	23-1 Luman	SW SW sec 23, T22N, R95W	Lewis Sh. Mesaverde Gp.	10,078-10,097 10,668-10,873	857 MCF 12 BBL cond 301 BBL H_2O	Wildcat discovery
	BP America Production	15-1 Luman	NE NW sec 15, T22N, R95W	Lewis Sh.	10,224-10,229 10,315-10,325	1.9 MMCF 87 BBL cond 87 BBL H_2O	Wildcat discovery
11	Burlingron Resources	5-28 MDU	SE NE sec 28, T39N, R90W	Fort Union Fm.	6192-6264	2.4 MMCF	New producer in Madden Field
	Burlingron Resources	99 MDU	SW NE sec 2, T38N, R90W	Fort Union Fm.	5536-5628 6650-6658	1.5 MMCF	New producer in Madden Field
	Burlingron Resources	91 MDU	SW SW sec 1, T38N, R90W	Fort Union Fm.	5475-5570	1.2 MMCF	New producer in Madden Field
12	Marathon Oil	58 Spring Creek	NE SE sec 11, T49N, R102W	Tensleep Ss.	4043-4091	717 BBL oil 2634 BBL H_2O	Spring Creek South Field development well
	Marathon Oil	57 Spring Creek	NE SE sec 11, T49N, R102W	Tensleep Ss.	4033-4120	358 BBL oil 419 BBL H_2O	Spring Creek South Field development well
	Marathon Oil	60 Spring Creek	NE SE sec 11, T49N, R102W	Tensleep Ss.	3804-4022	717 BBL oil 2634 BBL H_2O	Spring Creek South Field development well
13	Devon Energy	102-A28 Worland Unit	NE NE sec 28, T49N, R93W	Muddy Ss.	9995-10,028	262 MCF 105 BBL oil	New oil producer in Five Mile Field
14	Voyager Exploration	66-33 Silver Tip Unit	NW SE sec 33, T58N, R100W	Frontier Fm.	5997-6003	290 MMCF 466 BBL oil 70 BBL H_2O	New oil producer in Silver Tip Field
	Voyager Exploration	72-33 Silver Tip Unit	SE NE sec 33, T58N, R100W	Frontier Fm.	6109-6115	74 MCF 62 BBL oil	New oil producer in Silver Tip Field
15	Stone & Wolf LLC	SW 19-16 DK	SE SE sec 19, T47N, R69W	Mowry Sh.	7720-7820	80 MCF 60 BBL oil	Wildcat discovery
16	O'Brien Energy Resources	1H Greasewood	SW NW sec 1, T38N, R64W	Dakota Ss.	horizontal interval 6706-7134	160 BBL oil	Horizontal redrill of Dakota discovery

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; Gp.=Group. *Wyoming State Geological Survey, February, 2004.*

CALENDAR OF EVENTS

Talks

USE OF MAPS–*J.M. Huss*: Indian Paint Brush Elementary School, Laramie, Wyoming, March 26, 2004.

ESRI® ArcGIS® 9.0 TECHNICAL BRIEF–*J.M. Huss*: University of Wyoming, Laramie, Wyoming, March 22, 2004.

Meetings, conferences, exhibits, etc.

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS (AAPG) 2004 ANNUAL MEETING–*L. Cook*: Dallas Convention Center, Dallas, Texas, April 18-21, 2004.

DIGITAL MAPPING TECHNIQUES '04, CONVENED BY THE ASSOCIATION OF AMERICAN STATE GEOLOGISTS (AASG) AND THE U.S. GEOLOGICAL SURVEY (USGS)–*J.M. Huss and P.H. Ranz*: Portland State University and Oregon Department of Geology and Mineral Industries, Portland, Oregon, May 16-19, 2004.

COALBED METHANE FAIR–*various WSGS staff*: Campbell County Camplex, Gillette, Wyoming, June 3-4, 2004.

WYOMING MINING ASSOCIATION ANNUAL MEETING–*various WSGS staff*: Jackson Lake Lodge, Grand Teton National Park, Wyoming, June 16-18, 2004.

WYOMING STATE GEM AND MINERAL SOCIETY SHOW–*W.D. Hausel and other WSGS staff*: Rendezvous Center, Goshen County Fairgrounds, Torrington, Wyoming, June 19-20, 2004.

U.S. BUREAU OF LAND MANAGEMENT, OIL AND GAS CONFERENCE–*L. Cook and R.H. De Bruin*: Cheyenne, Wyoming, June 21-24, 2004.

2004 ROCKY MOUNTAIN SECTION AAPG MEETING AND ROCKY MOUNTAIN NATURAL GAS STRATEGY CONFERENCE AND INVESTMENT FORUM–*L. Cook, R.H. De Bruin, and R.W. Jones*: Colorado Convention Center, Denver, Colorado, August 9-11, 2004.

FIRST ANNUAL COALBED NATURAL GAS RESEARCH, MONITORING, AND APPLICATIONS CONFERENCE– *various WSGS staff*: Wyoming Union, University of Wyoming, Laramie, Wyoming, August 17-19, 2004.

37TH ANNUAL DENVER GEM AND MINERAL SHOW– *various WSGS staff*: Denver Merchandise Mart, 451 E. 58th Ave, Denver, Colorado, September 17-19, 2004.

WYOMING NATURAL GAS FAIR–*L. Cook and R.H. De Bruin*: Snow King Resort, Jackson, Wyoming, September 23-24, 2004.

ASSOCIATION OF EARTH SCIENCE EDITORS (AESE) ANNUAL MEETING–*R.W. Jones*: The Stanley Hotel, Estes Park, Colorado, November 3-6, 2004.

THE GEOLOGICAL SOCIETY OF AMERICA (GSA) ANNUAL MEETING AND EXPOSITION–*L. Cook, R.W. Jones, and other WSGS staff*: Colorado Convention Center, Denver, Colorado, November 7-10, 2004.

Courses

INTRODUCTION TO ArcGIS® ***I*****, ESRI® CERTIFIED COURSE–***J.M. Huss*: University of Wyoming, Laramie, Wyoming, March 29-30, 2004.

INTRODUCTION TO ArcGIS® ***I*****, ESRI® CERTIFIED COURSE–***J.M. Huss*: University of Wyoming, Laramie, Wyoming, August 18-19, 2004.

INTRODUCTION TO ArcGIS® ***I*****, ESRI® CERTIFIED COURSE–***J.M. Huss*: Laramie County GIS Coop, Cheyenne, Wyoming, November 12-13, 2004.

INTRODUCTION TO ArcGIS® ***I*****, ESRI® CERTIFIED COURSE–***J.M. Huss*: University of Wyoming, Laramie, Wyoming, November 17-18, 2004.

Coal Update

Robert M. Lyman, Wyoming PG-656

Staff Geologist–Coal, Wyoming State Geological Survey

Wyoming coal producers continued third quarter coal shipments that should make 2003 another record year, with 376.8 million short tons. Spot market prices pulled out of their first half doldrums. Healthy coal prices began to appear as electric utilities initiated their annual late-year surge to replenish depleted stockpiles for their winter needs. Over-the-counter spot prices for 8800-Btu coal from the Powder River Basin (PRB) were reported above the $7 per short ton range, and pricing appeared strong heading into 2004.

Early July rains created highwall problems at several large PRB coal mines, causing shipment times to slide—some consumers worried about getting needed coal to their power plants. Several utilities playing the low stockpile game wondered if the mines would be able to fill their third (and fourth) quarter needs. Unit train congestion on rail lines into and out of the PRB became more than just hypothetical, and talk began to surface on ways to control the annual second-half surge in demand for PRB coal. The major changes discussed would take cooperation from the suppliers, shippers, and buyers and will be hard to achieve in the short term.

Arch Coal's proposed acquisition of Triton Coal was tied up in the ongoing Federal Trade Commission review process and as of March, 2004, was yet to be decided. Arch Coal also reported progress on their joint venture with ADA-ES to market an enhanced coal product. A final environmental impact study (FEIS) was released on the exchange of coal properties that could lead to the development of a new coal mine in Sheridan County and progress was reported on the proposed new railroad line out of the PRB. The U.S. Department of Energy (DOE) announced the patenting of a new process that would remove mercury from flue gas emitted from coal-fired power plants. The process evidently works extremely well in lower rank coals and may be the solution to a problem that was facing many utilities burning PRB coal.

. . . DOE announced that a new mercury removal technique, known as the GP-254 Process, is showing promise for coal-burning power plants.

Production and prices

At the close of the third quarter, 2003, Wyoming coal production was about 277.5 million short tons, only about 0.9 million short tons more than the 2002 figure (**Table 13**). October, 2003 coal deliveries were substantially higher than those in October, 2002 and put us well on the way to another annual production record. Even with the usual turndown in shipments the last six weeks of the year, we feel confident that production will show the modest growth we predicted (**Tables 1** and **14**).

Monthly shipments of Wyoming coal for the first ten months of 2003 have climbed nearly every month of the year (**Figure 8**). Contract coal deliveries reported for the first ten months of 2003 have not shown the large monthly fluctuations seen in previous years (**Figure 9a**) and starting in July, spot sales picked up from the low levels earlier in the year (**Figure 9b**).

Like the increased deliveries, spot market prices for PRB coal also came out of the doldrums in the later part of July, and remained at a healthy level throughout the third quarter (**Figure 10**). Continued lack of available coal from the Central Appalachian region, problems in getting import coals, and some worries about rail congestion on the PRB joint line caused a third-quarter flurry of activity in the marketplace for Wyoming coal. The timely rise in spot market prices came as good news for the suppliers that entered into several major long-term contracts. The new contracts with these stronger prices should offset some of the lower prices predicted for the years ahead (**Table 2**).

Developments in the Powder River Basin

On September 16, 2003, the Wyodak Power Plant east of Gillette celebrated its 25th anniversary. The plant is unique to the state, in that it uses air-cooled generating units. Gillette's cool summers and very cold winters make air cooling possible, and the plant has remained the most trouble-free electrical generator on the grid. The plant is owned by Pacific Power and Light Company and Black Hills Power and Light Company and currently provides electricity to 170,000 customers located in five states.

Arch Coal signed a $1.3 million Securities and Investment Agreement with ADA-ES, a subsidiary of Earth Sciences, subject to completing a spin-off of ADA-ES as a separate public company. As part of the transaction, Arch will appoint a member to the Board of Directors of ADA-ES. In January, 2002, Arch and ADA-ES entered into a joint venture to market the ADA-ES enhanced coal product ADA-249, for use in cyclone-fired power plants. The product allows these plants to burn PRB coal with enhanced operational flexibility without increasing emissions. It also improves the marketability of combustion by-products (U.S. Coal Review, 7/21/03).

Table 13. Estimated monthly coal deliveries from Wyoming's mines in short tons (January, 1999 through October, 2003).

	1999		2000		2001		2002		2003	
	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative
January	27,105,791	27,105,791	27,773,610	27,773,610	27,743,000	27,743,000	28,406,666	28,406,666	31,421,669	31,421,669
February	25,803,390	52,909,181	25,594,109	53,367,719	27,827,000	55,570,000	30,041,748	58,448,414	28,087,977	59,509,646
March	28,222,743	81,131,923	28,262,696	81,630,415	33,739,000	89,309,000	33,409,797	91,858,211	30,282,095	89,791,741
April	25,965,867	107,097,791	25,549,039	107,179,454	27,302,000	116,611,000	27,534,057	119,392,268	29,882,355	119,674,096
May	28,698,498	135,796,288	26,222,515	133,401,969	27,752,000	144,363,000	34,704,299	154,096,567	30,893,000	150,567,096
June	24,753,829	160,550,118	25,085,516	158,487,485	33,968,000	178,331,000	26,674,488	180,771,055	30,790,082	181,357,178
July	28,266,458	188,816,576	28,881,862	187,369,348	29,200,000	207,531,000	27,885,210	208,656,265	31,608,733	212,965,911
August	28,346,757	217,163,333	29,075,295	216,444,642	27,662,000	235,193,000	35,670,535	244,326,800	32,402,820	245,368,731
September	27,373,417	244,536,749	25,865,389	242,310,032	35,369,000	270,562,000	32,234,471	276,561,271	32,169,561	277,538,292
October	26,837,296	271,374,045	26,441,615	268,751,646	29,869,000	300,431,000	26,101,957	302,663,228	34,981,708	312,520,000
November	26,843,021	298,217,066	27,400,246	296,151,892	29,308,000	329,739,000	32,767,619	335,430,847		
December	26,834,927	325,051,993	28,300,773	324,452,665	29,984,000	359,723,000	26,476,240	361,907,087		
Total Utility Tonnage[1]		**325,051,993**		**324,452,665**		**359,723,000**		**361,907,087**		
Total Tonnage Other[2]		**11,407,945**		**14,399,483**		**8,955,135**		**11,288,344**		
Total Tonnage Produced[3]		**336,459,938**		**338,852,148**		**368,678,135**		**373,195,431**		

[1]From Federal Energy Regulatory Commission (FERC) Form 423 for 1998; FERC Form 423 as modified by WSGS for 1999 through October, 2003. [2]Includes estimates of a residential, industrial, and exported coal. [3]Wyoming State Mine Inspector's Annual Reports. *Wyoming State Geological Survey, Coal Section, February, 2004.*

In August, 2003, the U.S. Bureau of Land Management (BLM) released its FEIS on the proposed land swap with Pittsburg & Midway Coal Mining Co. (P&M) that may lead to a new PRB mine in Sheridan County (see *Wyoming Geo-notes No. 75*, December, 2002, p. 15). The proposed land swap would give P&M 1234 acres of coal lands in Sheridan County containing an estimated 107 million short tons of coal. P&M hopes to develop their proposed Ash Creek mine on those reserves. In return, BLM and the federal government would get control of 5859 acres of various P&M Wyoming coal properties. A large portion in western Wyoming, approximately 2448 acres, would become part of Bridger-Teton National Forest (COAL Daily, 8/27/2003).

In early July, during a two-week period of heavy rains, Arch Coal and Kennecott Energy experienced some production problems at their mines related to highwalls. Peabody's North Antelope mine also had some conveyor belt problems they were able to quickly fix, but not before impacting their coal shipments. However, by mid-month, the area's mines were back loading trains in record numbers.

Arch Coal's planned acquisition of Triton Coal (see *Wyoming Geo-notes No. 78*, November, 2003) has been delayed by a second round of information requests from the Federal Trade Commission. The request is viewed as part of the normal review process and Arch hasn't speculated when the federal review will be satisfied. The waiting period applicable to the proposed acquisition, under the U.S. Hart-Scott-Rodino Antitrust Improvements Act of 1976, expires 30 days after substantial compliance with the request for information. The acquisition may not occur until 2004, so for now it is still a wait-and-see situation.

A tragedy at RAG Coal West's Belle Ayr mine took the life of one of their employees. Brad Beavers was struck by a tow hook attached to a tow strap being used to free a stuck pickup truck. The accident occurred on September 9, 2003; no one else was injured (COAL Daily, 9/12/2003).

Developments in southern Wyoming

Kiewit Mining has delayed submittal of its application for the proposed South Haystack mine near Kemmerer. The

Table 14. Wyoming coal production by county[1,2] (in millions of short tons) from 1996 to 2002, with forecasts to 2008.

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Powder River Basin												
Campbell County	246.3	274.1	294.3	299.5	329.5	332.8	334.8	337.6	340.4	343.3	346.1	350.0
Converse County	17.8	23.4	25.6	23.6	24.6	26.8	26.0	27.0	28.0	29.0	30.0	30.0
Sheridan County	M	M	M	M	0.0	0.0	M	M	M	M	M	M
Subtotal	264.1	297.5	319.9	323.1	354.1	359.6	360.8	364.6	368.4	372.3	376.1	380.0
Southern Wyoming												
Carbon County	5	3.5	2.7	2.0	0.5	0.7	2.0	2.0	2.0	2.0	2.0	2.0
Sweetwater County	7.8	9.2	9.4	10.0	9.5	8.6	9.0	9.0	9.0	9.0	9.0	9.0
Lincoln County	4.6	4.7	4.3	3.7	4.5	4.2	5.0	5.0	5.0	5.0	5.0	5.0
Subtotal	17.4	17.4	16.4	15.7	14.5	13.5	16.0	16.0	16.0	16.0	16.0	16.0
Total Wyoming[3]	**281.5**	**314.9**	**336.5**	**338.9**	**368.6**	**373.1**	**376.8**	**380.6**	**384.4**	**388.3**	**392.1**	**396.0**
Annual Change	**1.1%**	**11.9%**	**6.9%**	**0.7%**	**8.8%**	**1.2%**	**1.0%**	**1.0%**	**1.0%**	**1.0%**	**1.0%**	**1.0%**

[1]Reported tonnage from the Wyoming State Inspector of Mines (1997 through 2002). [2]County estimates by the Wyoming State Geological Survey, February, 2004 for 2003 through 2008. Totals may not agree because of independent rounding. [3]Estimate from CREG's Wyoming State Government Revenue Forecast, October, 2003. M=minor tonnage (less than a million short tons). *Wyoming State Geological Survey, Coal Section, February, 2004.*

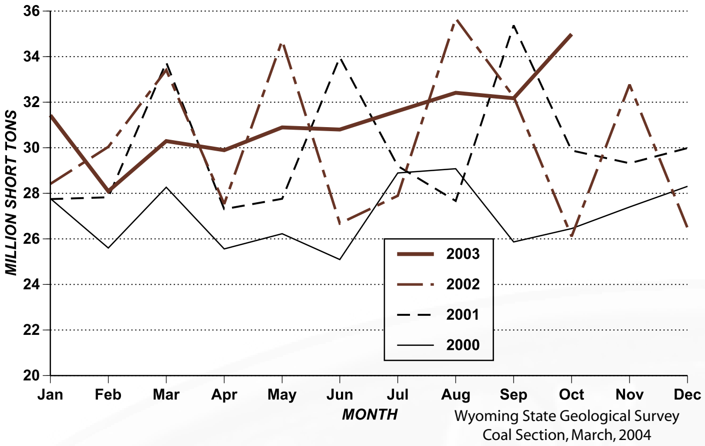

Figure 8. Reported monthly deliveries from Wyoming coal mines (January, 2000 through October, 2003). From Form 423 of the Federal Energy Regulatory Commission (FERC) as modified by the Wyoming State Geological Survey.

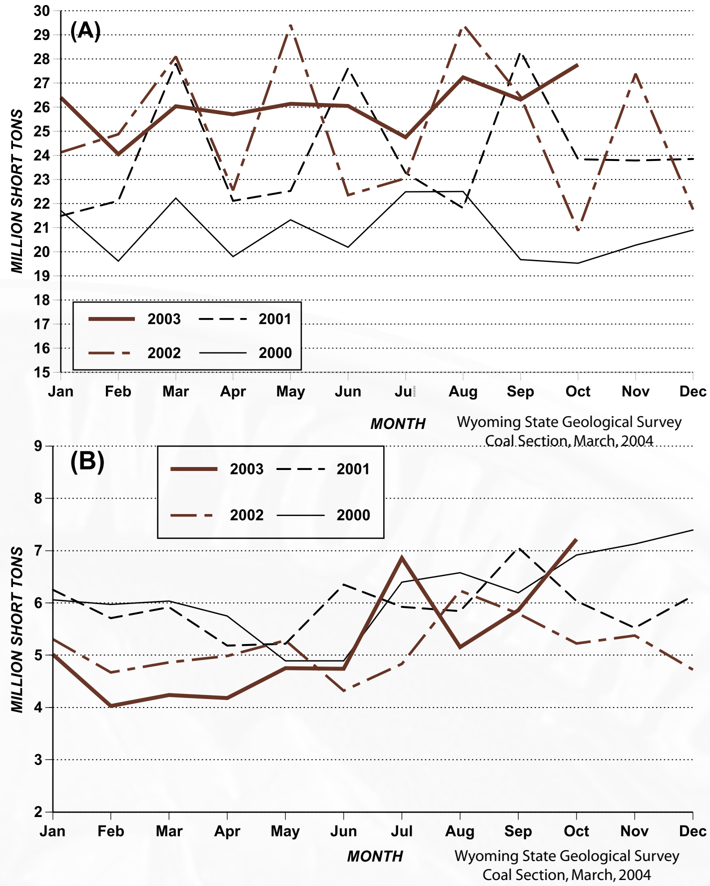

Figure 9. Monthly coal deliveries from Wyoming (January, 2000 through October, 2003). (A) Coal sold on contract and (B) coal sold on the spot market. From Form 423 of the Federal Energy Regulatory Commission (FERC) as modified by the Wyoming State Geological Survey.

delay is believed to be caused by some design concerns; the coal company is reportedly considering changing the location of the mining pit and the mine layout (U.S. Coal Review, 8/18/2003).

PacifiCorp's Jim Bridger Power Plant (**Figure 11**) was damaged by an August 25, 2003 fire that forced a shutdown of one of the plant's coal-fired units. The fire erupted inside the cooling tower for the 540-megawatt (MW) unit 3. It took fire crews six hours to put out the fire. Cause of the fire was traced to a faulty fan motor in the cooling tower and repairs shut the unit down for about a week (Coal Daily, 8/29/2003).

Transportation developments

The U.S. Forest Service has approved a five-year construction permit allowing the Dakota, Minnesota & Eastern Railroad (DM&E) to build track across part of the Thunder Basin National Grassland in northeastern Wyoming. The proposed build-in project would increase accessibility to coal mines in the PRB. The line is designed to move approximately 100 million short tons of coal per year out of the region, providing an important step in eliminating shipping bottlenecks in the southern PRB (U.S. Coal Review, 9/15/2003) and providing increased competition for coal transportation.

One of the Burlington Northern Santa Fe's (BNSF's) main east-west rail lines was closed briefly after 36 cars in a 123-car coal train derailed near the North Dakota State Penitentiary in Bismark the afternoon of July 5, 2003. No injuries were reported in the incident. Clean up of the coal spill and track repair was estimated to take up to two weeks. During the clean up and repair work, rail traffic was rerouted northward through Minot and Galesburg. The coal train was heading to Superior, Wisconsin from the PRB (U.S. Coal Review, 7/14/03).

Because of congestion on the railroads during the peak shipping period in the second-half of each year, coal producers in the PRB are becoming concerned about making timely deliveries to their utility customers in the future. Sales projections and production estimates for PRB coal indicate that the growing second-half bottleneck may ultimately affect coal suppliers, shippers, and buyers alike. Certainly, what affects one sector will eventually have repercussions on the other sectors.

It has been suggested that railroads revise their pricing based on unit train congestion on the joint rail line, making it a financial risk to delay shipments. Utilities (coal buyers) that wait until late in the year to build up their stockpiles may face economic penalties if they draw their stockpiles to record lows (as they did earlier in 2003). The railroads (coal shippers) could relieve some congestion by maintaining enough equipment to handle demand surges during peak shipping months. Some suggest that coal producers could adjust their production throughout the year to avoid or lessen the peak demand periods. Unfortunately, the latter could not guarantee that coal would be available to meet short-term needs of the consumers.

None of the three sectors can be excited about the above possibilities. All three suggestions would impact the economics of getting coal out of the ground, transported to the utilities, and supplying electricity to the consumer. Many conflicting issues will need to be addressed before a workable solution is reached, even as record coal tonnages continue to be delivered (U.S. Coal Review, 9/15/2003).

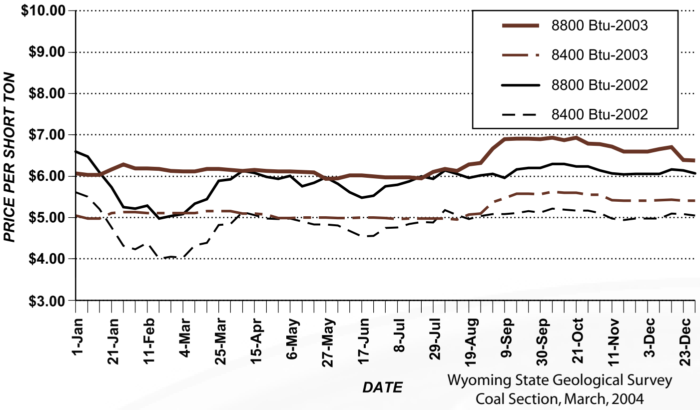

Figure 10. Wyoming Powder River Basin coal spot price watch (January 1, 2002 through December 31, 2003). Modified from COAL Daily's spot market index and Coal Week's short-term spot market price index.

Figure 11. The Jim Bridger Power Plant about 30 miles east of Rock Springs consists of four 530-MW generating units fueled by coal mined at the nearby Jim Bridger Coal Mine. Photograph by Richard W. Jones.

Regulatory developments

The National Energy Technology Laboratory at the DOE announced that a new mercury removal technique, known as the GP-254 Process, is showing promise for coal-burning power plants. In laboratory testing, the process easily removed more than 70% of the mercury from flue gases. Patented in June, 2003, the technique uses ultraviolet light to remove mercury from flue gas by exciting the mercury atoms, increasing their tendency to react with other compounds in the flue gas. DOE claims that the process is designed to work in existing pollution control devices, such as particulate collectors or wet scrubbers, and should work with all types of coals. It reportedly works best with lower rank coals such as subbituminous coal and lignite (Coal Daily, 8/8/2003).

A group interested in promoting Converse County as the most favorable site for DOE's proposed FutureGen project is bringing state and federal officials together to map out plans on attracting the attention of DOE officials. The project, which is designed as a combined effort of the private sector and the federal government, calls for building the first zero-emissions electricity- and hydrogen-producing plant. The plant would serve as a testing facility to help develop the next generation of coal-fired power technology. The Wyoming group believes that the Converse County site is ideal for its proximity to the nation's most prolific coal deposits, amongst other reasons. Other states pursuing the new project include Illinois, Texas, New Mexico, and Alabama. Final word on the sites to be considered should be announced sometime in early 2004.

The DOE is using aerial remote sensors to identify water sources such as mine impoundments and underground mine pools, with a primary focus on ground water. Remote sensors suspended from helicopters will help map the flow of groundwater that may be affected by energy projects, particularly coal mining and coalbed methane development. During the past summer, parts of Virginia, West Virginia, Wyoming, and Montana were scanned by the sensors. DOE hopes these scans will allow researchers to develop 3-D images of the flow of groundwater to subsurface depths of nearly 300 feet. In June, 2003 a series of flyovers surveyed approximately 50 square miles in the PRB; a second survey is planned for 2004. The results of both flyovers are intended to identify where the area's water comes from, how it flows through the area, and how it impacts groundwater, streams, and irrigation systems (Coal Daily, 9/4/2003).

Market developments and opportunities

City Public Service of San Antonio has announced plans to construct a new coal-fired power plant near Calaveras Lake, Texas. The 750-MW plant, which would be on-line by 2009, would be capable of meeting up to one-seventh of the utility's electrical demand. By 2013, the company estimates it will need 1500 MW of new generating capacity. Construction of the $1 billion project would begin in 2005 if the needed air permits are approved by the Texas Commission on Environmental Quality. Plans are to fuel the plant with coal from the PRB (U.S. Coal Review, 7/7/2003).

Progress Fuels is considering testing one or two train-loads of PRB coal at their Crystal River plant in Florida. The company is looking at several freight options including one that would rail the coal to Galveston, Texas and then barge it across the Gulf of Mexico to the west coast of Florida (U.S. Coal Review, 7/21/2003).

In the first week of September, 2003, Mid-American Energy broke ground on a $1.2 billion electrical generation facility in western Iowa, advertised as the first U.S. power plant to incorporate "advanced supercritical" technology. Construction will be completed in 2007, making the coal-fired energy complex the largest in Iowa. Supercritical boilers will create steam at higher pressures and temperatures than traditional coal-fired boilers; this will convert coal to electricity more efficiently and greatly reduce plant emissions. Over the next seven years, the company also plans to invest upwards of $300 million on environmental improvements to existing plants in their coal-fired system. The new 790-MW plant is being added to the company's 820 -MW Council Bluffs Energy Center. Coal from the PRB will be used to power the new high-tech boilers (U.S. Coal Review, 9/15/2003).

The 610-MW Parish #8 coal-fired unit near Houston, Texas went off line July 15, 2003 following a steam pipe rupture. Texas Genco, owner of the plant, said that repairs of the unit were completed on September 5. While the unit was down, the company made additional repairs scheduled for a planned three-week outage in November. The company also said it would install pipe monitoring devices on all four coal-fired units at the plant to help avoid similar problems in the future (COAL Daily, 9/15/2003).

Table 15 tabulates some of the contract, spot sales, test burns, and solicitations for Wyoming coal announced during the third quarter of 2003.

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Table 15. Marketing activities for Wyoming coal producers during the thrid quarter of 2003*.

Utility	Power Plant	Coal Mine/Region	Activity	Tonnage	Comments
Consumers Energy	System	PRB	So	3 to 12 mt/y	Delivery from 2005 through 2012
Consumers Energy	System	PRB	Sp	300,000 t	For 4th quarter 2003 delivery
Dairyland Power	System	PRB	So	Up to 1.85 mt/y	For five years beginning in 2004
FirstEnergy	System	Arch Coal/PRB	C	1 to 2.5 mt/y	Up to 5 years; 8800 Btu for delivery through 2007
Lower Colorado River Authority	Fayette Power Project	PRB	Sp	700,000 t	Delivery in 4th quarter of 2003 and all of 2004
Northern Indiana Public Service	Bailly and Schahfer	PRB	So	1 mt/y	For four years beginning in 2004
Omaha Public Power District	North Omaha & Nebraska City	Kennecott/PRB	C	2 mt/y	For five yearsbeginning in 2004
Omaha Public Power District	System	PRB	So	Up to 2 mt	Delivery in 2004
Salt River Project	Coronado	PRB	C	Tonnage not annouced	Terms not annouced
Texas Municipal Power Agency	Gibbons Creek	Cordero Rojo/PRB	C	Up to 1.5 mt/y	For five years; delivery to begin in 2004
Tennessee Valley Authority	System	Peabody EnergyPRB	C	170,000 t in 2003; 1.4 mt in 2004	Six-year contract, later year tonnages are uncertain
Western Fuels Association	Laramie Station	PRB	So	1 to 1.5 mt/y	For 3 years beginning in 2004

*Data obtained from: Coal Outlook, COAL Daily, U.S. Coal Review, FERC database, and personal contacts. Note: Btu = British Thermal Units; 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. *Wyoming State Geological Survey, Coal Section, February, 2004.*

Coalbed Methane Update

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Coalbed methane (CBM) production in Wyoming for three quarters of 2003 was about 259.4 billion cubic feet (BCF), with all but 1.6 BCF from the Powder River Basin (PRB) Coal Field. After a slow start to 2003, which saw monthly production rates falling during the first half of the year, CBM production picked up in the third quarter, and by October, daily production had nearly reached 1.0 BCF per day. Wyoming's CBM wells had produced nearly a fifth of the state's natural gas through three quarters of 2003. Development of CBM projects in southern and southwestern Wyoming continued as an exploration project in the southern Atlantic Rim area received the go-ahead, an environmental assessment (EA) was completed for another Atlantic Rim project, and an EA began for the Hay Reservoir area in the northern Great Divide Basin. Exploration projects were announced for the La Barge area in western Wyoming, the northern Hanna Basin, and northern PRB on the Montana-Wyoming border. Finally, a new study indicates that CBM production in the PRB could be dramatically increased by utilizing multi-seam completion technology.

Production

Statistics available from the Wyoming Oil and Gas Conservation Commission (WOGCC) through September, 2003 showed 12,012 producing and 3491 shut-in CBM wells across Wyoming. Production of CBM in the PRB through September of 2003 was 257.8 BCF, up 7.8% from the same period last year (**Table 16**). Statewide production of CBM for the first three quarters of 2003 averaged 28.8 BCF per month which is up 8.3% from the same period during 2002 (**Tables 16** and **17**).

Table 16. Monthly coalbed methane production from the Powder River Basin, Wyoming in MCF (January, 1999 through October, 2003).

	1999		2000		2001		2002		2003	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	3,660,420	3,660,420	8,465,248	8,465,248	18,216,791	18,216,791	25,853,518	25,853,518	29,461,089	29,461,089
February	3,462,675	7,123,095	8,706,458	17,171,706	16,918,619	35,135,410	23,386,057	49,239,575	26,372,716	55,833,805
March	4,110,431	11,233,526	9,864,450	27,036,156	19,829,335	54,964,745	26,055,646	75,295,221	28,901,024	84,734,829
April	4,040,981	15,274,507	10,549,945	37,586,101	19,705,398	74,670,143	25,391,303	100,686,524	27,943,685	112,678,514
May	4,422,524	19,697,031	11,824,542	49,410,643	20,712,168	95,382,311	27,266,936	127,953,460	28,736,336	141,414,850
June	4,605,477	24,302,508	12,196,467	61,607,110	20,517,257	115,899,568	26,382,980	154,336,440	28,145,169	169,560,019
July	4,877,860	29,180,368	13,031,976	74,639,086	21,849,659	137,749,227	27,930,264	182,266,704	29,019,037	198,579,056
August	4,793,060	33,973,428	14,185,648	88,824,734	22,408,968	160,158,195	28,687,800	210,954,504	29,883,071	228,462,127
September	5,125,791	39,099,219	14,403,249	103,227,983	21,659,652	181,817,847	28,225,335	239,179,839	29,314,262	257,776,389
October	5,961,184	45,060,403	15,396,043	118,624,026	24,110,581	205,928,428	29,254,930	268,434,769	30,312,201	288,088,590
November	5,947,893	51,008,296	15,233,376	133,857,402	24,099,231	230,027,659	28,996,365	297,431,134		
December	7,180,697	58,188,993	16,903,406	150,760,808	25,703,879	255,731,538	29,717,465	327,148,599		
Total		**58,188,993**		**150,760,808**		**255,731,538**		**327,148,599**		**288,088,590**

Data from the Wyoming Oil and Gas Conservation Commission. MCF = thousands of cubic feet. Wyoming State Geological Survey, February, 2004.

Acquisitions

Galaxy Energy Corp. purchased all the CBM leases held by Pioneer Oil LLC. These leases account for 15,600 acres in the PRB CBM play. Pioneer, a Wyoming-based company, transferred all of its holdings to Galaxy for $1 million in cash and two million shares of Galaxy's common stock. The acquisition landed Galaxy five existing natural gas wells and access to a 20-inch gas transmission line that crosses the leased property.

A subsidiary of Wyoming-based U.S. Energy Corp. and Crested Corp., Rocky Mountain Gas Inc. (RMG), has signed a purchase agreement to acquire CBM properties in the PRB (PI/Dwights Plus Drilling Wire, 12/24/2003). The property includes 247 completed wells that produce roughly 8.1 million cubic feet (MMCF) of gas per day (gross). RMG will only acquire a portion of this production, which is about 4.2 MMCF per day (net) from two properties that cover 12,602 acres located near Gillette. Also included in the sale are 40,000 acres of undeveloped properties including 28,000 acres in the PRB that are prime areas for CBM development and production.

Activities

The U.S. Bureau of Land Management (BLM) issued an EA for the proposed Doty Mountain CBM Project in Carbon County. According to PI/Dwights Plus Drilling Wire (10/30/2003), the project is in the Atlantic Rim Environmental Impact Statement (EIS) study area, T17N, R91W (**location A, Figure 7**) and was proposed by Warren E & P Inc., Double Eagle Petroleum Co., and Anadarko E & P Co. This project is one of nine pods that make up the Atlantic Rim Interim Drilling Project. The project will entail drilling, completing, testing, operating, and reclaiming 24 exploratory CBM wells in target coals of the Upper Cretaceous Mesaverde Group. The produced water will be injected via two wells into deeper aquifers with waters of lesser quality. New roads, utility lines, and production facilities will be constructed. The life of the project is estimated between 10 and 20 years.

Dallas-based Merit Energy Co. has been given the go-ahead to implement their Brown Cow Pod project by the BLM (PI/Dwights Plus Drilling Wire, 12/19/2003). The project area covers roughly 1600 acres along the eastern flank of the Washakie Basin. Up to three injection wells and 12 CBM exploratory wells will be drilled in the northeastern corner of T14N, R91W, 12 miles north-northwest of Baggs in Carbon County (**location B, Figure 7**). The project will help acquire more data to prepare the Atlantic Rim EIS and was approved by BLM's Rawlins Field Office. An Interim Drilling Policy was sent out to participating operators. Data collected from this project will aid in assessing the CBM potential and future development in the Atlantic Rim area. The field office issued a record of decision (ROD) and a "finding of no significant impact" after examining the potential environmental impacts contained in the EA for this project.

The BLM began an EA for the proposed Hay Reservoir CBM Natural Gas Pilot Project 25 miles northwest of Wam-

Table 17. Monthly coalbed methane production from other Wyoming coal fields in MCF (January, 2000 through October, 2003).

	2000		2001		2002		2003	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	31	31	1,594	1,594	21,118	21,118	123,681	123,681
February	119	150	1,982	3,576	12,069	33,187	115,247	238,928
March	167	317	2,486	6,062	6,737	39,924	162,466	401,394
April	366	683	2,738	8,800	6,713	46,637	157,434	558,828
May	637	1,320	4,255	13,055	8,640	55,277	179,883	738,711
June	1,494	2,814	5,149	18,204	32,691	87,968	177,829	916,540
July	992	3,806	5,453	23,657	39,716	127,684	215,265	1,131,805
August	1,417	5,223	3,329	26,986	52,391	180,075	216,409	1,348,214
September	1,459	6,682	2,993	29,979	69,082	249,157	223,563	1,571,777
October	1,165	7,847	2,667	32,646	71,672	320,829	225,103	1,796,880
November	1,335	9,182	4,434	37,080	77,640	398,469		
December	1,317	10,499	39,232	76,312	99,629	498,098		
Total		**10,499**		**76,312**		**498,098**		**1,796,880**

Data from the Wyoming Oil and Gas Conservation Commission. MCF = thousands of cubic feet. Wyoming State Geological Survey, February, 2004.

sutter (T23N, R97W) in northeastern Sweetwater County (**location C, Figure 7**). According to an article in the Casper Star-Tribune (9/20/03), this pilot project could determine the potential for and the economic feasibility of CBM development within the Great Divide Basin. The target coals are in the Tertiary Fort Union Formation. Kennedy Oil Company hopes to drill eight CBM wells and one injection well for water disposal. Kennedy's 22-well exploratory CBM project (in Ts24 and 25N, R98W) to the northwest was approved by BLM earlier (see *Wyoming Geo-notes No. 78*, November, 2003), but that project was briefly halted in late August until additional analysis of the EA and the ROD was completed.

. . . CBM production in the PRB could be dramatically increased by utilizing multi-seam completion technology.

Another CBM project in southwestern Wyoming is moving forward. Infinity Oil & Gas Inc. (Infinity) signed a cooperative agreement with Schlumberger Oilfield Services and Red Oak Capital Management LLC. to develop the La Barge CBM project (PI/Dwights Plus Drilling Wire, 12/12/2003). The project area covers nearly 25,000 acres in Sublette County and will focus on revitalizing existing wells in the Thompson and Riley Ridge pilot areas (**location D, Figure 7**). The project will proceed based on favorable annual evaluations. At the end of 2003, Schlumberger began work on the initial completion of existing drill holes within the project area. Under the agreement, Infinity only designated a third of its drill sites for the cooperative agreement, leaving the remainder of its holdings to be developed at their own pace.

Anadarko E & P Co. L.P. is planning a wildcat well targeting Tertiary coals in the Hanna Formation on the northern flank of the Hanna Basin, section 23, T24N, R81W (**location E, Figure 7**). The Application for Permit to Drill (APD) calls for a 6760-foot deep well 11 miles north-northwest of the town of Hanna in Carbon County. The proposed site is two miles north-northeast of Barrett Resources' 14-35 Hanna Draw Unit (PI/Dwights Plus Drilling Wire, 12/9/2003).

St. Mary Land & Exploration Co. announced plans to develop CBM reserves in the Hanging Woman Basin coal deposit along the Wyoming-Montana border (**location F, Figure 7**) (PI/Dwights Plus Drilling Wire, 12/3/2003). The company has leased 126,000 acres in the CBM play of the PRB. In 2001, St. Mary initiated two pilot projects that evaluated potential gas reserves within five coal seams. The results enabled the company to estimate a net probable reserve of 150 BCF. Development of the area will begin in 2004 with first anticipated gas sales in 2005. The project will be operated by St. Mary's wholly owned subsidiary, Nance Petroleum Corp. of Billings, Montana.

Regulatory issues

A recent study released by the U.S. Department of Energy (DOE) Office of Fossil Energy indicates that CBM production in the PRB could be dramatically increased by utilizing multi-seam completion technology (MSC) (PI/Dwights Plus Drilling Wire, 10/24/2003). The report was prepared by Advanced Resources International Inc. John R. Duda of the National Energy Technology Laboratory reported that this study was basically an impact analysis funded by the DOE in an effort to understand the effectiveness of MSC with regard to both increased gas reserves and decreased production cost. Early attempts to utilize MSC in the PRB showed unfavorable results. The new study was given inertia by the President's National Energy Policy, which estimated that U.S. natural gas consumption could increase up to 50% over the next 20 years.

Industrial Minerals and Uranium Update

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Production of the major industrial minerals in Wyoming continued mostly steady in the third quarter of 2003. A major glass manufacturer, Owens-Illinois (O-I), announced that it had received a contract to manufacture beer bottles for Budweiser and construct a bottle plant near Budweiser's brewery north of Fort Collins, Colorado. O-I will contract for a silica sand source, and may prefer one nearby. Wyoming Gray Sandstone®, used on the outside of the Wyoming State Capitol and other buildings is now being quarried near Rawlins and fabricated by Strid Marble and Granite of Cheyenne.

The major nonfuel minerals produced in the state in order of value are trona, bentonite, helium, limestone reported as cement (U.S. Geological Survey, 2003), construction aggregate, and gypsum. Helium is classified as an industrial mineral by the U.S. Geological Survey (USGS).

Uranium continues to be produced at two *in situ* localities in Wyoming. The price of yellowcake increased by a large amount, from $10.90 per pound at the end of the second quarter of 2003 to $14.50 per pound at the end of 2003.

In the fall of 2003, Wyoming State Geological Survey (WSGS) Public Information Circular 42, entitled *Decorative stones of southern Wyoming*, by R.E. Harris, was released. This 55-page, full-color report describes 60+ sites in southern Wyoming that have potential for decorative or dimensional stone and aggregate production. Quarriable dimensional stone sites are described in terms of accessibility and joint and fracture spacing; location maps for the sites are provided. For ordering information, see the press release on the WSGS web site or the **New Publications** section at the back of this publication.

Bentonite

Bentonite production for the third quarter continued at a level about the same as for each of the first two quarters of 2003. Seven companies operated thirteen plants in Wyoming (**Figure 12**). At each operation, bentonite of different properties is mined from separate pits and hauled to a mill, where it is blended into products of specific and consistent quality.

Cement

Cement is listed by the USGS as an industrial mineral commodity. The USGS estimates that 100 million short tons of cement were produced in the U.S. in 2003, slightly more than the 99 million short tons produced in 2002 (van Oss, 2004). Mountain Cement near Laramie (**Figures 12** and **13**), the only cement plant in Wyoming, produced 0.67 million short tons of cement, or only 0.67% of the U.S. production. Nevertheless, the production of cement is an important contributor to the economy of Albany County and Wyoming.

Cement is not, however, a mined substance but is produced from limestone, gypsum, and lesser amounts of other materials. Almost 900,000 short tons of limestone were mined in Wyoming in 2002 and 670,000 short tons of cement were produced. The ratio is not exact, since some limestone may have been stockpiled for next year's production. Limestone is roasted in a large rotating kiln (there are two at Mountain Cement, see **Figure 13**) then ground in a ball mill into a substance called clinker. Gypsum is added as a retardant to make the cement dry evenly and at a predictable rate. Siliceous shale is added as a strengthener and to give the cement desired properties. Small amounts of iron and other materials are selectively added depending on the cement product desired. These ingredients are again heated, and ground into the final products. In the past, marl (impure limestone containing silica) was added instead of siliceous shale.

This method varies a little from plant to plant depending on the quality of the raw materials. Mountain Cement uses nearly pure limestone. At Nevada Cement in Fernley, Nevada, no silica is added because their limestone is impure, and contains the right amount of silica. In certain areas of the eastern U.S., pure limestone is scarce or difficult to mine, so dolomite is used instead. In Finland, no limestone is found, so Precambrian marble (metamorphosed limestone) is used as the major ingredient.

At the Mountain Cement plant, limestone from quarries located 5 to 15 miles east and southeast of the plant (**Figure 12**), gypsum from about 6 miles south of the plant (**Figure 12**), and siliceous shale from 8 miles southwest of the plant (**Figures 12** and **14**) were used. The limestone is from the Pennsylvanian Casper Formation, the gypsum is from the Triassic Chugwater Formation, and the siliceous shale is from the Cretaceous Mowry Shale.

Construction aggregate

Construction aggregate production in Wyoming is mainly seasonal and peaks during the summer's highway and outdoor structure construction season. Construction during

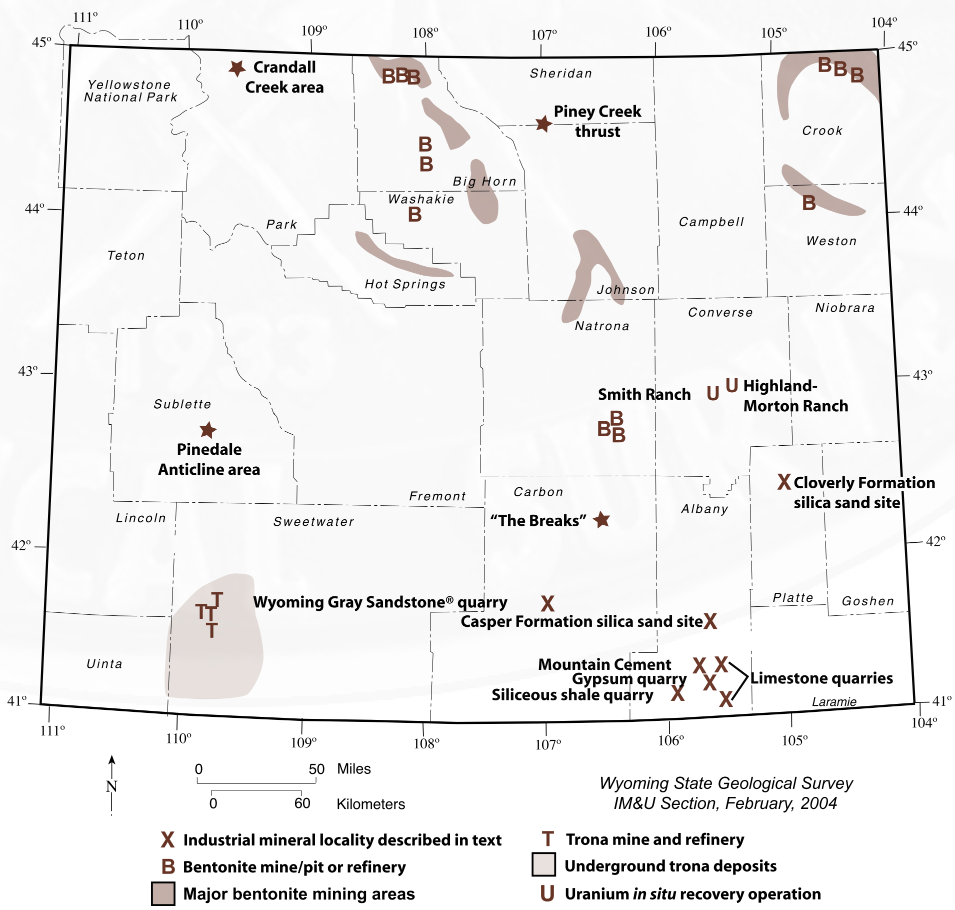

Figure 12. Index map of Wyoming showing the location of industrial mineral and uranium sites described in the text, selected mining areas, and locations of newly published studies on Wyoming geology (stars). Locations are approximate and may represent more than one site.

Figure 13. Mountain Cement's cement plant south of Laramie.

Figure 14. Siliceous shale quarry operated by Mountain Cement southwest of Laramie.

the summer of 2003 remained strong, so the construction aggregate production should stay high for 2003.

Decorative and dimensional stone

Strid Marble and Granite of Cheyenne has reopened a dimensional sandstone quarry southeast of Rawlins (**Figures 12** and **15**). The stone that faces the Wyoming State Capitol Building, the Union Pacific Railroad Depot in Ogden, Utah, the old Wyoming State Penitentiary, some buildings on the University of Wyoming campus, and probably others is from this quarry. The stone is being marketed as Wyoming Gray Sandstone®.

The market for moss rock, flagstone, and fieldstone remains strong. These products from Wyoming are sold regionally to markets along the Wasatch front of Utah, the Front Range of Colorado, and in developing ski towns of Colorado. Some stone has also been sold as far away as California and Chicago. There were about 12 producers in Wyoming at the end of 2003.

Silica sand

Silica sand is the primary ingredient in the manufacture of glass. Soda ash, the primary product refined from Wyoming's natural trona deposits (see below), is the secondary ingredient. Silica sand occurs as high-silica (SiO_2) sandstone from windblown or beach deposits. In Wyoming, sandstones in the Cretaceous Cloverly Formation (Harris, 1988a) in Platte County (**Figure 12**) and Pennsylvanian Casper Formation (Harris, 1988b) in Albany County (**Figure 12**) may qualify as silica sand. So far, Wyoming's extensive active and inactive Recent sand dune fields have not been found to contain silica of sufficient grade. Other factors such as the presence of certain impurities (especially chromium) and the grain size distribution affect a particular sandstone's use in glass manufacture.

In early 2003, O-I, a major manufacturer of glass, announced that it had obtained a contract to manufacture beer bottles for Budweiser's brewery north of Fort Collins, Colorado. At the end of 2002, O-I announced it was planning to construct the plant in an industrial park near Windsor, east of Fort Collins. O-I would like to complete the plant by mid-year 2005. It is not known where the silica sand for this plant would come from, but O-I has indicated to a couple of silica sand producers that it would like to use a local source.

Trona

Trona is mined in Wyoming at four underground mines and refined into soda ash and other sodium compounds at mine-mouth plants. Four companies (FMC, General Chemical Soda Ash Partners, OCi, and Solvay Minerals) operate the mines and refining plants (**Figure 12**). Trona mining and soda ash production in Wyoming in 2003 should be near the same level as 2002. The USGS (Kostick, 2004) predicts a worldwide increase in soda ash production between 1.5 and 2%.

FMC closed the trona mine and soda ash refining plant at the Granger site in late 2002 (**Figure 16**). They continue to keep the mine accessible for possible reopening, but at the end of 2003 had not made a decision regarding permanent closure. FMC operates the larger mine and refining plant at Westvaco.

Figure 15. Wyoming Gray Sandstone® quarry site southeast of Rawlins, circa 1988.

Early in 2003, Solvay joined FMC Westvaco in operating a longwall miner. In this method, trona is continuously removed from a face several hundred feet in width. The unit advances towards the face, supporting the roof near the face with hydraulic covers. Following the passage of the longwall, the roof is allowed to collapse behind it. This method results in a higher rate of recovery than other methods of mining. All four trona producers mine by a room-and-pillar method using conventional mining equipment.

Uranium

The spot market price of yellowcake (the product of Wyoming's uranium mills) jumped during the second half of 2003 from $10.90 per pound to $14.50 per pound, according to the Ux Consulting Company, LLC., The Uranium Exchange Company (http://www.uxc.com/review/uxc_prices.html), and the Rocky Mountain Minerals Scout. Yellowcake is uranium oxide with a varying amount of other elements, having no definite chemical formula. The price increase is not due to a corresponding increase in U.S. demand, but may be a reflection of the strengthening U.S. economy.

Figure 16. Aerial view of FMC Granger soda ash plant, now mothballed. Photograph by John R. Dyni, 1998.

Uranium is produced in Wyoming at two *in situ* recovery sites, Smith Ranch and Highland/Morton Ranch by Power Resources, a subsidiary of CAMECO (**Figure 12**). CAMECO, of Saskatoon, Saskatchewan, also owns the only other current uranium production in the U.S. at Crow Butte, Nebraska.

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Metals and Precious Stones Update

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During the past quarter, additions were made to the Metals and Precious Stones Section's part of the Wyoming State Geological Survey's (WSGS') web site including: (1) a section on searching for placer diamonds; (2) some new photos of faceted stones from Wyoming, and (3) some updates to the Section's searchable bibliography (see http://www.wsgsweb.uwyo.edu/metals/).

The Section applied for a STATEMAP grant to map three 1:24,000-scale quadrangles in the Leucite Hills area near Rock Springs. The Section had originally proposed mapping the Rock River 1:100,000-scale Quadrangle for STATEMAP 2004 (see **Geologic Mapping, Paleontology, and Stratigraphy Update**) but another group is reportedly completing this quadrangle. The Section is updating parts of the 1:500,000-scale *Metallic and industrial minerals map of Wyoming*, WSGS Map Series 14, and is continuing to compile geologic maps that will be used for a bedrock geologic map of the Saratoga 1:100,000-scale Quadrangle. This is a STATEMAP 2003 project, funded by a grant from the U.S. Geological Survey and scheduled for completion in August, 2004.

During the past quarter, the Section published an article in the *Northern Miner* (January, 2004) on metal and gemstone prospects and exploration opportunities in Wyoming. The *Northern Miner* is an exploration summary published in Canada. The Section also published a paper on placer diamonds in the December issue of ICMJ's *Prospecting and Mining Journal*.

Rock Hound's Corner: Iolite (Cordierite)–A Little Known Gemstone Recently Discovered in Wyoming

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Gem-quality cordierite is known to gemologists as *iolite*, and sometimes referred to as *dichroite*. Typically, the mineral iolite has oily to vitreous luster, and may be sapphire-blue in color with marked pleochroism, causing the gem to change color from sapphire-blue to violet-blue to gray-blue as the mineral is rotated in light. *Pleochroism* is the result of certain wavelengths of light that are absorbed along different crystallographic directions. Minerals such as iolite that exhibit two pleochroic colors are said to be *dichroic*, which is why iolite is sometimes referred to as "dichroite" by some collectors and gemologists.

The pronounced pleochroism in iolite was apparently taken advantage of by Vikings. It is thought that the Vikings used transparent slices of iolite as navigational aids on cloudy days so that they could tell the sun's position by observing partially polarized light from the sky through the strongly pleochroic mineral (Hurlbut and Switzer, 1979).

Cordierite may be opaque, translucent, or transparent. When it is transparent to translucent, the mineral may be gem quality. Some gem cordierite, when cut, appears similar in appearance to sapphire. This along with its pleochroism makes iolite a popular gemstone.

To a mineralogist, cordierite $(Mg, Fe^{3+})_2Al_4Si_5O_{18}$ is orthorhombic and often forms short prismatic pseudohexagonal crystals with rectangular cross sections. Massive, compact mineral grains of various shades of blue, bluish-violet, gray, or brown are also found in nature. According to Sinkankas (1964), repeated twinning (on *m*{110}) produces cordierite crystals of nearly hexagonal cross section. Cordierite exhibits poorly developed cleavage. Parting (parallel to *m*{001}) may occur in some altered crystals.

In Wyoming, cordierite has been found in some pelitic schists (biotite and muscovite schists) with other aluminosilicate minerals (i.e., andalusite, sillimanite, and/or kyanite). It has also been found in anorthosite south of Sybille Canyon. When unaltered, cordierite has a hardness of 7 and low specific gravity of 2.55 to 2.75 (the specific gravity increases with increasing iron content).

Most cordierite found in Wyoming has been poor-quality opaque to translucent, white-gray to brown material. Until recently, little was known about gem-quality cordierite (iolite) in Wyoming. But following the spectacular discovery of gem-quality cordierite in the Palmer Canyon area west of Wheatland by the Wyoming State Geological Survey (Hausel, 1998), several excellent gems have been produced along with some gem-quality ruby, pink sapphire, and semi-precious kyanite (**Figures 17** and **18)** (for color versions of these photographs, see: http://www.wsgsweb.uwyo.edu/metals/gemstones.asp). Gem specimens of iolite weighing up to 1714 carats were found by the author in Palmer Canyon.

Other iolite gems are likely to be found in Wyoming. In particular, several cordierite occurrences are reported in the Laramie Mountains; it has also been reported in the Owl Creek Mountains, Wind River Range, Sierra Madre, and Seminoe Mountains.

One of the more interesting descriptions of iolite was published by Sinkankas (1959):

> *Iolite is a widespread constituent of schistose and gneissic rocks in the Laramie Range of Albany County. One estimate has placed the quantity available at thousands of tons. Specimens from this locality examined by the author are glassy broken fragments of rather light blue color, verging toward grayish; small sections are clear and suitable from faceted gems. It is entirely possible that important amounts of gem quality material will be produced from this area in the future.*

Unfortunately, the location of this deposit was not given. However, it is thought that this deposit may be within the Laramie Mountains anorthosite complex. Locations of known Wyoming cordierite deposits are reported by Hausel and Sutherland (2000).

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Figure 17. Three sapphire-blue faceted iolite gems from Palmer Canyon. Photograph by Robert W. Gregory.

Figure 18. Gemstones from Palmer Canyon. The middle gemstone is a nearly flawless 1.1-carat sapphire. The cabochon in the upper right is a semi-precious 1.4-carat pinkish-brown sapphire. The other gemstones are blue faceted iolites. These are owned by Vic Norris of Lyons, Colorado.

GEOLOGIC MAPPING AND HAZARDS UPDATE

Geologic Mapping, Paleontology, and Stratigraphy Update

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The Wyoming State Geological Survey (WSGS) submitted a proposal for STATEMAP 2004 to the U.S. Geological Survey (USGS) in November, 2003. Four subprojects were proposed: mapping and compiling the bedrock geology of the Midwest 1:100,000-scale Quadrangle; digitizing two 1:24,000-scale maps (Keystone and Barlow Gap quadrangles) and four 1:100,000-scale maps (bedrock geology of Casper and Saratoga quadrangles and surficial geology of Rock River and Saratoga quadrangles); mapping and compiling the bedrock geology of the Rock River 1:100,000-scale Quadrangle; and continuing work on the bedrock geology of the Torrington 1:100,000-scale Quadrangle.

Two searchable databases are currently available online that allow the user to determine if published geologic mapping is available for specific areas. The two databases, Wyoming Internet Map Server and the National Geologic Map Database, are served by the University of Wyoming (UW) and the USGS, respectively.

The American Association of Petroleum Geologists (AAPG) recently published three articles relating to Wyoming geology and paleontology. The articles include topics relating to depositional remnants as possible hydrocarbon traps in Cretaceous rocks and a discussion of a new technique for modeling fracture intensity, emphasizing the Pinedale anticline.

The latest issue of Rocky Mountain Geology contains structural papers relating to the tectonic evolution of the Proterozoic Colorado province, a new interpretation of the Piney Creek thrust on the eastern flank of the Bighorn Mountains, and a discussion of the Blacktail thrust-fold associated with the Heart Mountain detachment. In addition, this volume includes a discussion of a Paleocene mammal-bearing locality in the northeastern corner of the Hanna Basin and a profile of pioneer geologist Nelson Horatio Darton.

STATEMAP 2004 projects proposed

In November, 2003, the WSGS proposed four mapping projects for the STATEMAP 2004 Program. The four projects (**Figure 19**) are: 1) to map and compile the bedrock geology of the Midwest 1:100,000-scale Quadrangle; 2) to digitize bedrock geologic maps of the Casper and Saratoga 1:100,000-scale quadrangles and the Keystone and Barlow Gap 1:24,000-scale quadrangles, and to digitize surficial geologic maps of the Rock River and Saratoga 1:100,000-scale quadrangles; 3) to map and compile the bedrock geology of the Rock River

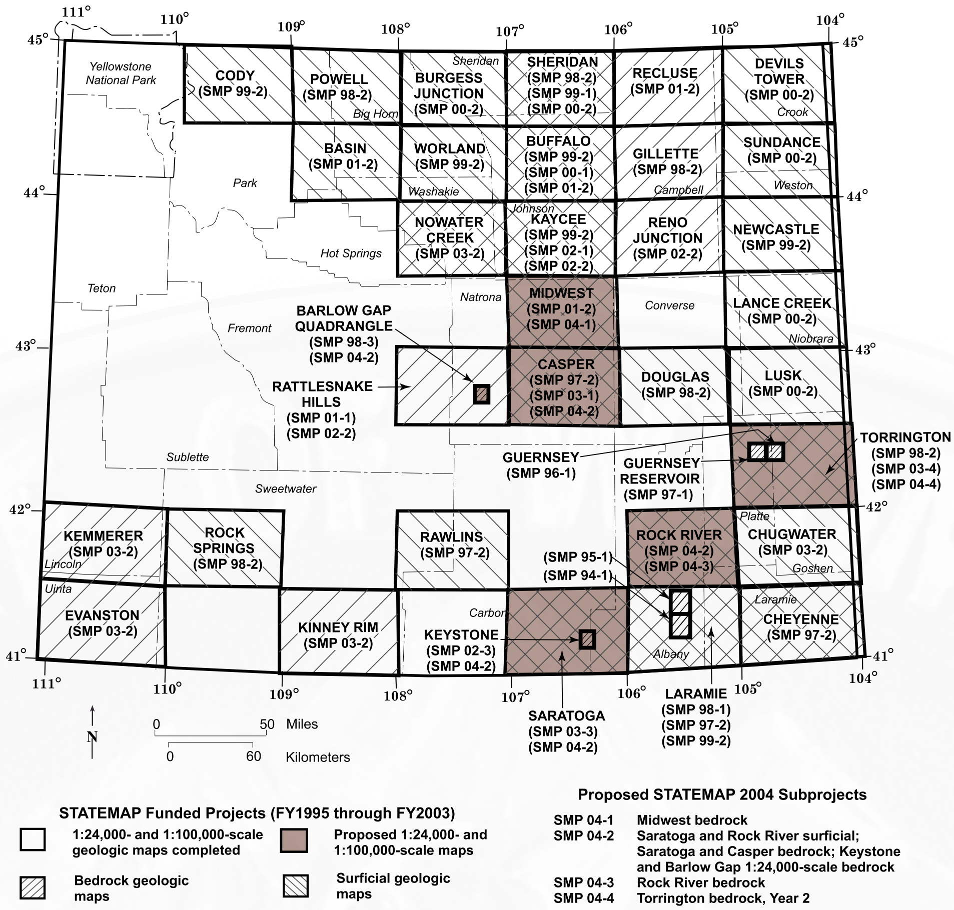

Figure 19. Index to proposed, in-progress, and completed STATEMAP projects in Wyoming.

1:100,000-scale Quadrangle; and 4) to continue compilation and mapping of the bedrock geology of the Torrington 1:100,000-scale Quadrangle. Current 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 (PRB) 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, and 3) mapping to support mineral exploration and development.

The Mapping Section proposed to map and compile the bedrock geology for the Midwest Quadrangle with funding from STATEMAP 2004. Completion of this map will augment southward expansion of the recently completed Northern Powder River Basin geologic, hydrologic, and water quality database project. This map will also complete the north-south column of quadrangles along the western flank of the PRB and eventually all the quadrangles in the northeastern quadrant of the state (**Figure 19**). Efforts on Midwest will concentrate on compiling the numerous existing maps, incorporating some unpublished work in the northern section of the map, and edge matching with the Kaycee Quadrangle to the north and the Casper Quadrangle to the south.

The Midwest Quadrangle is located in the central part of Wyoming (**Figure 19**) and includes bedrock ranging in age from Pennsylvanian to Paleocene. The dominant structural features include a portion of the Casper Arch and the Salt Creek/Teapot Dome anticlinal complex, with their associated structures. The northwest part of the map includes folds and faulting on the southern end of the Bighorn uplift. The axis of the PRB runs northwest to southeast, approximately 10 to 15 miles east of the quadrangle.

The Mapping Section will review and compile the previously mapped parts of the quadrangle, complete the unmapped parts, and prepare a preliminary black line geologic map. The preliminary map (released as a WSGS open file report) will then be digitized, with the final version published as a color geologic map in the WSGS map series. Funding from STATEMAP 2004 will be used to acquire any needed aerial photography, negatives and orthophoto sheets for the base maps, for paying a part-time geological assistant and a GIS technician to begin digitizing, and for field vehicle rental and travel expenses.

The Publications Section proposed digitizing the Casper and Saratoga 1:100,000-scale and the Keystone and Barlow Gap 1:24,000-scale bedrock geologic maps (**Figure 19**). Compilation of the Casper and Saratoga quadrangles is currently in progress under STATEMAP 2003; the Keystone and Barlow Gap quadrangles are published as open file maps (hard copy only). In addition, the Section will digitize the surficial geologic maps for the Rock River and Saratoga 1:100,000-scale quadrangles. These two maps are currently unpublished paper maps completed by the Hazards Section of the WSGS. For all six proposed maps, the geology layer will be scanned, converted from a raster image to a vector image, and edited for consistency with National Digital Mapping Standards. STATEMAP 2004 funding will be used to acquire existing 1:100,000-scale digital topographic and public land survey data from EROS Data Center, for paying a part-time GIS assistant, and for map scanning costs.

The Metals and Precious Stones Section proposed to map and compile the bedrock geology for the Rock River 1:100,000-scale Quadrangle as a two-year project (**Figure 19**). This quadrangle lies in a very important region of the central Laramie Mountains of eastern Wyoming that includes the eastern extension of the 1.7 Giga-annum or billion years before present (Ga) Cheyenne Belt (shear zone) reportedly exposed in the Richeau Hills. The Cheyenne Belt separates the Archean Wyoming Province (>2.5 Ga) from younger cratonized Proterozoic Green Mountain Terrain (1.7 to 1.9 Ga) to the south. The quadrangle also includes the northern Laramie Mountains anorthosite-syenite complex (1.5 Ga), the southern margin of the Elmers Rock greenstone belt (>2.5 Ga), and the eastern margin of the Phanerozoic Laramie Basin. Funding from STATEMAP 2004 will be used to acquire any needed aerial photography, negatives and orthophoto sheets for the 1:24,000/1:100,000-scale bases, for paying a part-time geological assistant, and for field vehicle rental and travel expenses.

The Mapping Section, in cooperation with UW's Institute for Energy Research, created a searchable Wyoming geologic map database served online.

The Industrial Minerals and Uranium Section proposed continuing to map and compile the bedrock geology for the Torrington 1:100,000-scale Quadrangle (**Figure 19**). This will be the second year of a two-year project. The quadrangle includes Paleozoic and Tertiary rock outcrops with some Precambrian and Mesozoic exposures. The primary structural feature in the area is the Hartville uplift. The Section completed the Guernsey and Guernsey Reservoir 1:24,000-scale quadrangles as part of STATEMAP 1996 and 1997. These two maps, along with other existing mapping, will be used to compile the geology. Some fieldwork will be required to close any gaps in the existing mapping. Funding from STATEMAP 2004 will be used to hire a geological assistant and for field vehicle rental and travel expenses.

Geologic map indices for Wyoming geology

The WSGS and specifically the Mapping Section has been traditionally responsible for compiling indices for published Wyoming geologic maps. The Section's initial efforts in the late 1980s produced a series of index maps showing geologic mapping from the WSGS, the USGS, and in-state theses and dissertations from UW. These index maps, organized by geologic map type, were published as 19 separate 1:1,000,000-scale sheets in hard copy (WSGS Map Series 9A through 9S). The time and manpower needed to produce these indices and the fact that they are quickly outdated has prompted the Section to develop alternate avenues for timely compilation and updates.

The Mapping Section, in cooperation with UW's Institute for Energy Research, created a searchable Wyoming geologic map database served online. A user selects an area and the browser displays the existing data. Currently, a search returns a bibliographic listing of geologic maps in the selected area; the database can also be searched for additional types of data. If desired, the retrieved data can be printed via the browser print command.

The web site is currently maintained by UW's Wyoming Geographic Information Science Center (WyGISC) as part of the Wyoming Oil and Gas Resource Assessment Mapper. This Wyoming Internet Map Server allows the user to pan, zoom, and query multiple maps and databases of Wyoming. The address for the web site is http://www.wims.uwyo.edu/. Map data is current through 1996, but unfortunately the database is not easily updated.

The Section's most recent effort involved entry of geologic map data for Wyoming into a National Geologic Map Database (NGMD) maintained by the USGS. The database is searchable with a complete list of geologic maps completed for each state. The Wyoming portion of the database includes USGS, WSGS, UW, and out-of-state university thesis and dissertation maps. The Section completed 228 entries for WSGS-published geologic maps and reports containing geologic maps and provided the data to the USGS for inclusion in the NGMD. The Section used funding from STATEMAP 2001 to enter data on geologic maps from UW theses and dissertations from 1890 to the present. The Section recently submitted 26 new geologic map entries for WSGS publications, making the database current through 2003. We are compiling data for WSGS unpublished landslide maps. Data on new geologic maps can be entered directly into the database using an online entry form making it very easy to keep the database current.

The NGMD web site address is http://ngmsvr.wr.usgs.gov/ngmdb/ngm_compsearch.html. This site allows the user to search the database for geologic and other geoscience-related maps using one or more of the following search criteria: Geologic Themes, State or Territory, County or 100K Quad, Bounding Coordinates, Author, Title, Map Number, Cross Section, Product Format, Map Scale, Date, and Publisher. After completing the initial query steps, the search engine will respond with a list, in bibliographic form, of maps and data sets found. The list is ordered first by scale, then by author.

New articles on Wyoming geology

In a recently published article, Wong (2003) described a new technique for modeling fracture intensity based on a case study from Wyoming's prolific Pinedale anticline natural gas play (**Figure 12**). The author presented recently developed computer techniques that can be used to improve reservoir fracture characterization and identification of potential sweet spots within Pinedale anticline. Using rock matrix properties and a fracture-related seismic attribute, a simulated 3-D fracture intensity model was developed for Pinedale anticline.

Martinsen (2003a; 2003b) recently completed a two-part article on depositional remnants within the stratigraphic record that can have significant implications for hydrocarbon exploration and production. The author examines the preservation of porous and permeable sedimentary strata encased in low-permeability facies often created by erosional truncation. These types of features are more common than previously thought and can range in size from one to several square kilometers, making them potentially significant stratigraphic traps. The first article describes these types of features. The second article outlines examples from the Western Interior Cretaceous basin, specifically the Almond Formation of the eastern greater Green River Basin; the Muddy Sandstone and Upper Cretaceous hydrocarbon reservoirs of the PRB; the Cardium Formation of Alberta, Canada; the Teapot Sandstone Member of the Mesaverde Formation in the PRB; the Tocito Sandstone of the San Juan Basin, New Mexico; and the Shannon Sandstone Member of the Cody Shale in the PRB.

The Department of Geology and Geophysics at UW released the Fall, 2003 issue of the journal *Rocky Mountain Geology*. This issue contains five excellent new articles pertaining to Wyoming geology. Sims and Stein (2003) summarized the tectonic evolution of the Proterozoic Colorado Province of the Southern Rocky Mountains, including the Sierra Madre and Medicine Bow Mountains of Wyoming and the Front Range of Colorado. A new interpretation of the Piney Creek thrust and associated Granite Ridge tear fault in the northeastern Bighorn Mountains was presented by Stone (2003). The author uses geologic mapping, seismic-reflection data, gravity data, and borehole data to reinterpret the Piney Creek thrust (**Figure 12**), extending it to the north in the subsurface possibly as far as the Tongue River lineament near the Montana border. The Granite Ridge fault is redefined as a true tear fault confined to the hanging wall of the Piney Creek thrust. Beutner and DiBenedetto (2003) reinterpreted the Blacktail anticline in northwestern Wyoming (**Figure 12**) as a thrust-fold, using the depositional characteristics of the Crandall Conglomerate (Eocene) as evidence. New field work in the area and re-examination of the Crandall Conglomerate suggested this interpretation; the authors concluded that the Blacktail anticline is similar to other late Laramide structures in the area. Higgins (2003) described a succession of Paleocene mammal-bearing localities in Wyoming, which bracket the boundary between the Torrejonian and Tiffanian North American Land Mammal "Ages." The fossil localities examined are located in an area locally referred to as "The Breaks," near the northeastern corner of the Hanna Basin (**Figure 12**). Finally, Snoke (2003) profiled the amazing career of Nelson Horatio Darton, an early geologist with the USGS. Darton did much of his reconnaissance geologic mapping on horseback and is responsible for much of the early geologic mapping in Wyoming, Nebraska, and South Dakota.

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Flood Map Modernization Program

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Floods can and have caused significant damage in Wyoming and are one of the more significant natural hazards in the state. Flood Insurance Rate Maps (FIRMs) are important in defining safe areas to build and live. The Federal Emergency Management Agency (FEMA) generates or funds the generation of these maps, which delineate 100-year and 500-year flood boundaries. FEMA's Map Modernization Program allows the State of Wyoming to participate in decisions regarding the remapping of FIRMs. The Geologic Hazards Section at the Wyoming State Geological Survey (WSGS) generated an updated Multi-Hazard Flood Map Modernization State Business Case Plan for Wyoming, a program in which the State of Wyoming will participate at a mid-level. In addition, Wyoming has proposed initiating a Flood Mapping Coordination Program, which will serve as an interface between communities and FEMA, if needed. The Program will also establish web sites to facilitate information dissemination and communication.

FEMA has a goal of reducing the average age of FIRMs to six years. Currently, only 5% of all FIRMs are six years or less in age.

Introduction

Floods are one of the more significant natural hazards in Wyoming, and can cause millions of dollars in damage in just a few hours or days. Maps that show where flooding may occur are necessary for the protection of property and life. FEMA generates or funds the generation of FIRMs which delineate 100-year and 500-year flood boundaries. For example, **Figure 20** shows part of a FIRM for Douglas. Various flood zones are shown on this map and those described below. Zone A (shaded) delineates the 100-year flood boundary (1% chance of being flooded in any year). Zones B and X (also shaded) delineate the areas between the 100-year and the 500-year flood boundaries (0.2% chance of being flooded in any year). Zone C and Zone X (unshaded) are areas of minimal flooding potential.

Digital Flood Insurance Rate Maps (DFIRMs) are new digital flood maps based on a digital orthophoto quadrangle base. Part of a DFIRM for Dubois is shown in **Figure 21**. The DFIRMs are easier to use than regular printed FIRMs with topographic bases because actual structures and features can be observed in relation to flood boundaries.

As can be seen on both the Douglas and Dubois maps, there are different variations on Zone A. Zone AE (new maps) and Zones A1 to A30 (older maps) are areas where detailed Flood Insurance Studies (FIS) have been conducted and base flood elevations have been determined. These maps are the most defensible if questions regarding precise flood boundaries develop.

FIRMs are based upon the best available flood and stream discharge data, as well as the best topographic base map available at the time the FIRM was generated. In some cases, however, little reliable historical data are available, and base maps are old and inaccurate. As a result, the FIRM may be generated based only upon a best estimate of where a flood may occur. For example, the Chugwater FIRM (**Figure 22**) shows that roads on the FIRM do not match the roads on a current topographic base. In addition, parts of Chugwater Creek lie outside the 100-year flood boundary shown on the map. The map obviously needs to be redone.

History of flood map modernization

FIRMs in Wyoming range from fairly old to new. If an area is experiencing growth, a FIRM that is six years old may not be adequate, as new structures in or near a floodplain can affect base flood elevations. Similarly, if a FIRM is in an area where no growth has occurred, a 15-year-old map may still be adequate. There are some areas in Wyoming where base maps used to generate a FIRM are so inaccurate that the FIRM will be inadequate regardless of population growth.

The Geologic Hazards Section at the WSGS generated a Flood Map Modernization Plan for Wyoming in August, 2002. The plan prioritized FIRMs individually and counties as a whole in regards to remapping or mapping needs. There are currently 417 FIRMs in Wyoming, ranging in age from 1974 to 2002 (**Table 18**). FEMA has a goal of reducing the average age of FIRMs to six years. Currently, only 5% of all FIRMs are six years or less in age. Slightly more than 2% of unincorporated area FIRMs and approximately 21% of incorporated area FIRMs are six years or less in age. Except

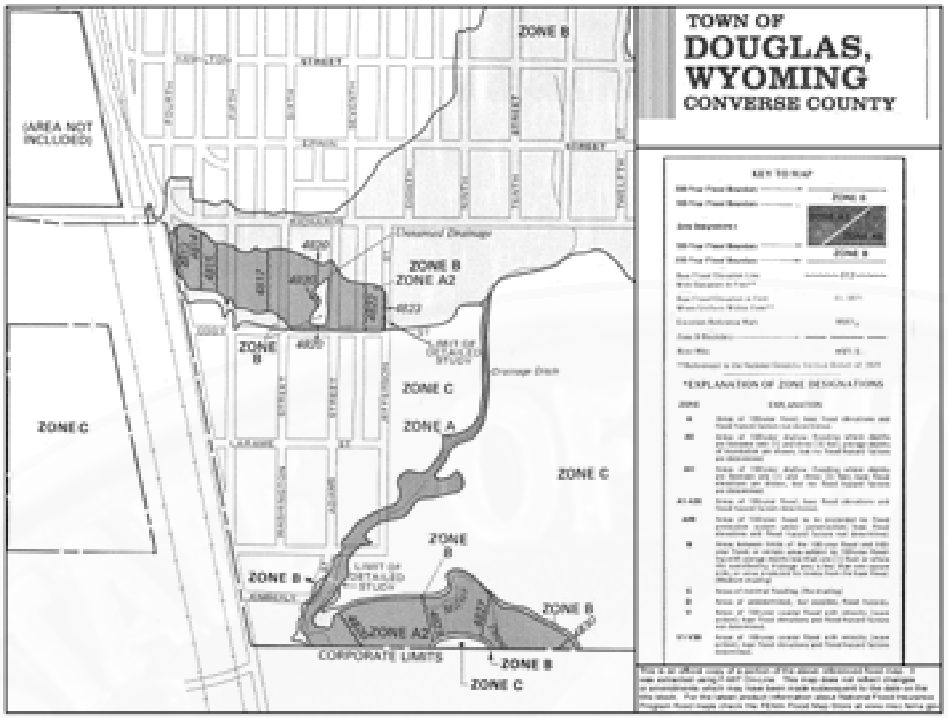

Figure 20. Example of a FIRM for part of the town of Douglas, Wyoming. Zones indicate areas of flooding, inundation, etc. for different events, as described in the text.

for the Dubois, Casper, Evansville, and Mills area FIRMs, all maps were included in the analysis for the 2002 Map Modernization Plan for Wyoming (**Table 19**). The Casper, Evansville, and Mills FIRMs have been completed and approved, and will be released in mid-2004.

In the 2002 Map Modernization Plan for Wyoming, all individual FIRMs were analyzed and ranked based upon map age, mapping status (mapped or unmapped panel), repetitive loss, participation in National Flood Insurance Program (NFIP), and approximate population increase within 250 feet, 500 feet, and 1000 feet of each side of all streams in a panel or jurisdiction (**Table 20**).

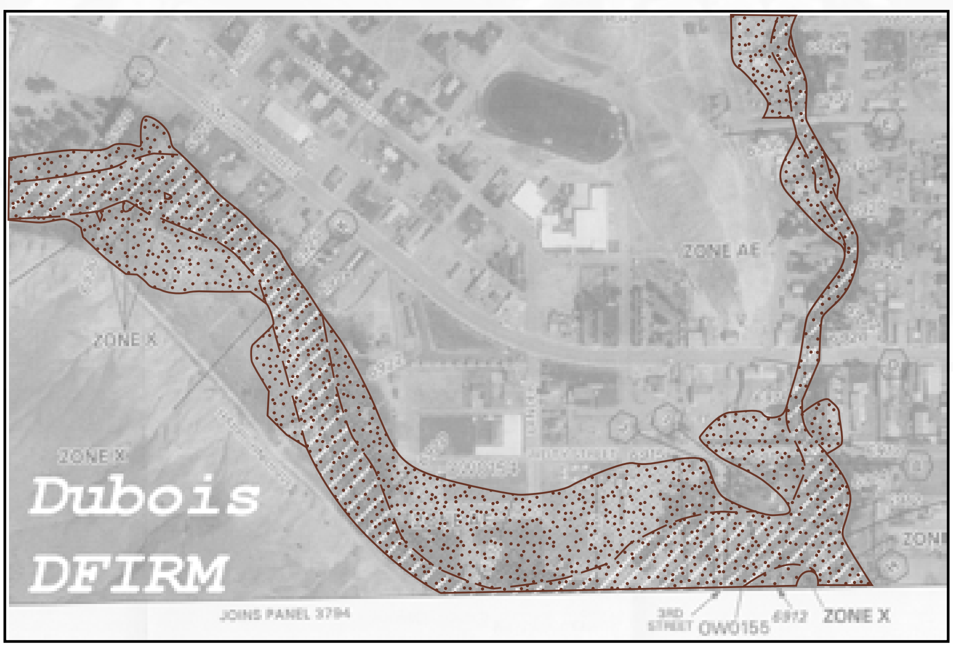

Figure 21. Example of a DFIRM, which shows the flood zones superimposed on an orthophoto. Hachured area is the floodway. This is a DFIRM for part of the town of Dubois.

Table 18. Number of flood insurance rate maps by map age.

Map year	Incorporated area FIRMs	Unincorporated area FIRMs	Total FIRMS
2002	7	0	7
2001	1	0	1
2000	1	0	1
1999	3	0	3
1998	2	8	10
1997	0	0	0
1996	1	0	1
1995	0	0	0
1994	2	4	6
1993	0	0	0
1992	1	0	1
1991	0	32	32
1990	0	0	0
1989	2	33	35
1988	4	11	15
1987	3	17	20
1986	5	3	8
1985	1	0	1
1984	1	20	21
1983	1	0	1
1982	6	15	21
1981	0	0	0
1980	2	19	21
1979	2	4	6
1978	4	71	75
1977	1	113	114
1976	2	0	2
1975	7	0	7
1974	8	0	8
Total	**67**	**350**	**417**

Table 19. Ten-year FIRM history for Wyoming.

Year Completed	Jurisdiction	Panel number
1994	Cheyenne	5600300010
		5600300005
	Laramie County	5600290660
		5600290655
		5600290520
		5600290515
1996	Laramie	5600200005
1998	Rock Springs	5600510005
	Sheridan County	5600470027
		5600470020
		5600470013
		5600470012
		5600470011
		5600470005
	Cokeville	5600330001
	Lincoln County	5600320800
		5600320785
1999	Ranchester	5600460001
	Thermopolis	5600260001
	East Thermopolis	5600250001
2000	Green River	5600500005
2001	Sheridan	5600440005
2002	Newcastle	5600570027
		5600570026
		5600570007
	Dubois	5600183813
		5600183794
		5600183792
		5600183791
2004	Casper Evansville Mills	Panel Numbers Not Available

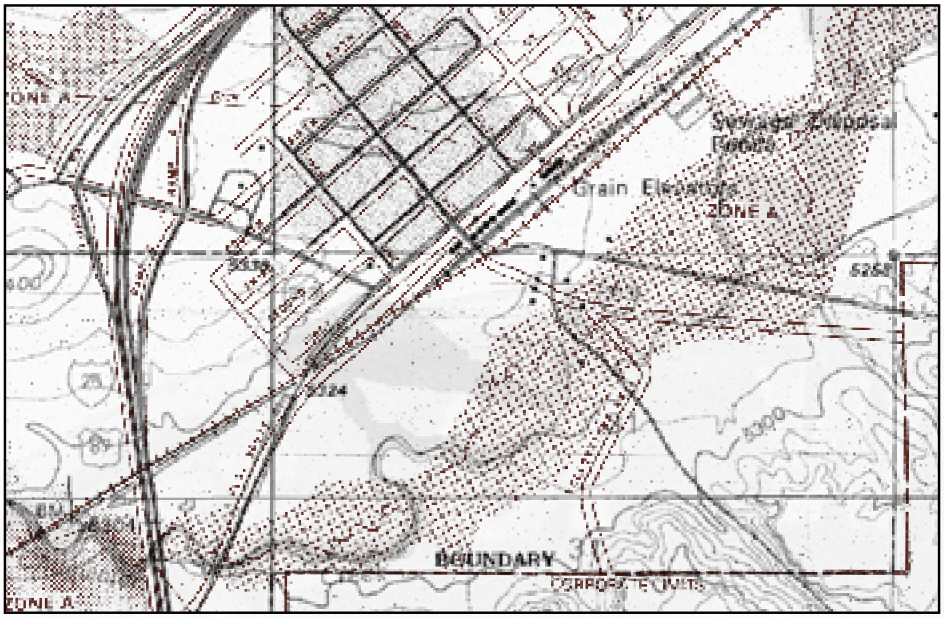

Figure 22. FIRM for part of the town of Chugwater. Mapped flood zones and other features from the FIRM are shown in brown, superimposed on the 1:24,000-scale topographic quadrangle (black).

After individual FIRMs were ranked, FEMA determined that a ranking of counties would be preferable. The WSGS developed a numeric county ranking scheme that was biased towards population. The population within FIRMs with ranks of 4.75 and higher and within 500 feet of streams was summed for each county. This sum was used as the overall rank for the county, with the greatest population receiving the highest rank. The list of counties was then divided into three groups, creating high, medium, and low rankings (**Table 21**).

Table 20. FIRM panel priority ranking scheme.

Map age		Category	Ranking
Age	Ranking	Repetitive loss	
0 – 5	0	None	0
6 – 11	3	Loss	1
12 – 17	3.5	Participation in NFIP	
18 – 23	4	Participate	0.5
24 – 29	4.5	Non-Participate	0
		Unmapped community	
		Unmapped	2
		Mapped	0

Population increase (by panel)			
Increase (number of people)	250' buffer distance ranking	500' buffer distance ranking	1000' buffer distance ranking
1 – 20	0.75	0.5	0.25
21 – 50	1	0.75	0.5
51 – 100	1.5	1.25	1
101 – 500	2	1.75	1.5
501 – 1000	2.5	2.25	2
1000 +	3	2.75	2.5

Current and proposed mapping projects

Currently, FEMA and their subcontractors have initiated or will soon initiate a number of mapping projects in Wyoming, as shown in **Table 22** (Mr. John Liou, FEMA Region VIII, personal communication, 2004). The projects are listed in order of their initiation date.

FEMA has also developed a list of probable future mapping projects for the State of Wyoming (Mr. John Liou, FEMA Region VIII, personal communication, 2004). The list was in part based upon the 2002 Wyoming Map Modernization Plan and in part upon analysis conducted by FEMA. The probable mapping projects include the Cheyenne area (Laramie County), Kemmerer (Lincoln County), Douglas and North Platte River (Converse County), Hulett (Crook County), and Thermopolis area (Hot Springs County).

Table 21. County mapping priorities, 2002.

County name	Priority rank	Population within 500' of streams in critical panels	Priority category
Natrona	1	12,313	High
Teton	2	5,776	High
Laramie	3	5,207	High
Albany	4	3,589	High
Campbell	5	3,322	High
Fremont	6	3,246	High
Uinta	7	2,803	High
Park	8	2,530	High
Converse	9	1,442	Medium
Lincoln	10	1,328	Medium
Big Horn	11	1,221	Medium
Sweetwater	12	1,089	Medium
Sheridan	13	1,069	Medium
Sublette	14	954	Medium
Johnson	15	949	Medium
Platte	16	551	Medium
Goshen	17	471	Low
Carbon	18	402	Low
Washakie	19	338	Low
Crook	20	176	Low
Niobrara	21	169	Low
Hot Springs	22	0	Low
Weston	23	0	Low

Map modernization business plan

In February, 2004, the Geologic Hazards Section generated an updated Multi-Hazard Flood Map Modernization State Business Case Plan for Wyoming (Case and Dobler, 2004). The State of Wyoming will begin participation in the Multi-Hazard Flood Map Modernization Program at a mid-level. At this level, the State will perform a majority of the mapping-needs assessment and will assist with outreach and community coordination on mapping projects. However, the State will not manage or perform any flood mapping activities. The FEMA Regional Office will manage all mapping activities based upon input provided by the State. The State of Wyoming will strive to increase their level of participation in future years.

The State of Wyoming will establish a Mapping Coordination Program at the WSGS, with funding for a position and travel supplied through FEMA and the Wyoming Office of Homeland Security/Emergency Management (WOHS/EM). The Program will coordinate with WOHS/EM on all activities. The Program will conduct or coordinate the following activities:

Table 22. Current FIRM mapping projects by Federal Fiscal Year (FFY).

FFY project initiation date	Mapping area
2001	Sundance (Sundance Creek)
2002	Laramie County (Allison Draw)
2003	Worland (Mary River) Worland (Sage Creek) Teton County (Flat Creek, Snake River)
2004	Kaycee (Powder River)
2004 (Proposed)	Albany County Fremont County Campbell County

- Update the business plan yearly.
- Conduct a survey of all cities, counties, state agencies, and federal agencies to determine the status of digital base mapping, digital contour maps, and digital photography.
- Acquire or link to all possible base maps, contour maps, and digital photography.
- Acquire all possible flood data, flood histories, and community profile information.
- Serve maps, history, flood data, and community profiles on a WSGS web site. A prototype web site already has FIRMs available for viewing, and digitized FIRMs will be available on the site by May, 2004.
- Coordinate with all communities in Wyoming in regards to Map Modernization and determine community mapping needs. A Floodplain Administrator Questionnaire was the first step in this process. Site visits will be coordinated with administrators.
- Generate flood analyses and preliminary flood boundary maps using HAZUS MH. Compare generated maps with digitized FIRMs to determine quality of both products.
- Encourage community participation in the Cooperating Technical Partners (CTP) Program.
- Work with WOHS/EM and FEMA on enhancing the education of floodplain administrators in regards to local hazards and the need for Map Modernization.
- Coordinate with FEMA on mapping needs, and provide input on priority areas.
- Assist FEMA with outreach and community coordination on mapping projects.
- Build a partnership among state, federal, local, and private agencies and organizations in Wyoming that will enable Wyoming to accept greater responsibilities in the Map Modernization Program, and will encourage more communities to participate in the CTP Program.
- Organize and participate in outreach activities, to include mailings, meetings, and multi-media promotional activities.
- Work towards a higher level of participation in the Map Modernization Program.

Future mapping projects by year are derived and updated from the Map Modernization Plan (MMP) for Wyoming. There has been mapping progress since the county priority rank was proposed in the 2002 MMP (**Table 21**). The rankings are now updated to reflect this progress (**Table 23**). Natrona County has been remapped, and there is an ongoing project in Teton County. The Teton County project does not include all mapped panels; many of the panels not included in the current project contain private levees. Private levees cannot be certified by FEMA, so the existing panels will remain unchanged (Mr. Dan Carlson, FEMA Region VIII, personal communication, 2004). There is an ongoing project along Allison Draw in Laramie County, and the City of Cheyenne/Laramie County have requested that mapping be accomplished through their CTP agreement with FEMA. Albany, Campbell, and Fremont counties, the three counties with the highest mapping priorities, are planned for mapping by FEMA in FY2004 (**Table 22**). Joining the list for 2004, is the town of Kaycee, which experienced a disastrous flood on the Middle Fork of the Powder River in the summer of 2002 (**Figure 23**). Mapping priorities will be evaluated yearly and incorporated into yearly updates of the Business Plan.

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Table 23. County mapping priorities, 2004.

County name	Priority rank	Population within 500' of streams in critical panels	Priority category
Albany	1	3,589	High
Campbell	2	3,322	High
Fremont	3	3,246	High
Uinta	4	2,803	High
Park	5	2,530	High
Converse	6	1,442	Medium
Lincoln	7	1,328	Medium
Big Horn	8	1,221	Medium
Sweetwater	9	1,089	Medium
Sheridan	10	1,069	Medium
Sublette	11	954	Medium
Johnson	12	949	Medium
Platte	13	551	Medium
Goshen	14	471	Low
Carbon	15	402	Low
Washakie	16	338	Low
Crook	17	176	Low
Niobrara	18	169	Low
Hot Springs	19	0	Low
Weston	20	0	Low

Figure 23. A flash flood on the Middle Fork Powder River west of Kaycee inundated the town on August 27, 2002. This photograph, which was taken two days later, shows standing water in the street. The house in the center was hit hard and along with another house behind it, had to be torn down. Photograph courtesy of Wyoming Emergency Management Agency.

Tectonic Implications of Tertiary Paleo-stream Channel Deposits and Erosion Surfaces in the Rattlesnake Hills, Natrona County, Wyoming

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Characteristics of three Tertiary features, consisting of Oligocene stream deposits, post-Miocene stream deposits, and an Oligocene erosion surface, support earlier interpretations of the tectonic history of central Wyoming. Systematic lithologic changes in the Oligocene stream deposits indicate drainage reversal in the southern half of the Rattlesnake Hills and large-scale regional warping and faulting of the Ancestral Granite Mountains in central Wyoming during the late Cenozoic. The younger (Plio-Pleistocene) set of stream deposits formed south of the Rattlesnake Hills after the Granite Mountains subsided in the Miocene. A postulated original northward gradient on a remnant of the Oligocene erosion surface is used to estimate a minimum of 3200 feet of subsidence of the central part of the Granite Mountains. This evidence supports the existence of a major east-west trending mountain range in central Wyoming during the middle Tertiary as determined by Love (1970).

Introduction

The tectonic development of central Wyoming revolves around the Granite Mountains, the major structural feature present there. This west-trending Laramide uplift is deeply eroded, partially buried, and marked by a series of prominent knobs and ridges of Precambrian granite, granite gneiss, hornblende schist, and small amounts of banded iron formation. The Rattlesnake Hills are an eroded, northwest-trending, Laramide anticline on the north flank of the Granite Mountains (Pekarek, 1977; 1978). The North Granite Mountains fault system provides a convenient boundary between the Rattlesnake Hills on the north and the Granite Mountains on the south (**Figure 24**). The Precambrian rocks exposed in the Rattlesnake Hills contain "a fragment of a partially exposed synformal Archean greenstone belt within the Wyoming craton" (Hausel, 1996, p. 1). Although Hausel (1995; 1996) has mapped the Precambrian metamorphic rocks of the Rattlesnake Hills in great detail, in this paper they are referred to by the general term hornblende schist.

Paleo-stream channel deposits were first mapped in the Rattlesnake Hills by Pekarek (1974). Subsequently, the extensive deposits along UT Creek have been mapped in progressively more detail by Pekarek (1976; 1978), Hausel (1996), and Sutherland and Hausel (1999). The present paper adds further details on the distribution and lithology of the channel deposits and discusses their tectonic implications for the Rattlesnake Hills and the adjacent Granite Mountains.

Paleo-stream deposits

Two sets of paleo-stream channel deposits are observed in the Rattlesnake Hills area: a northern set dated as Oligo-

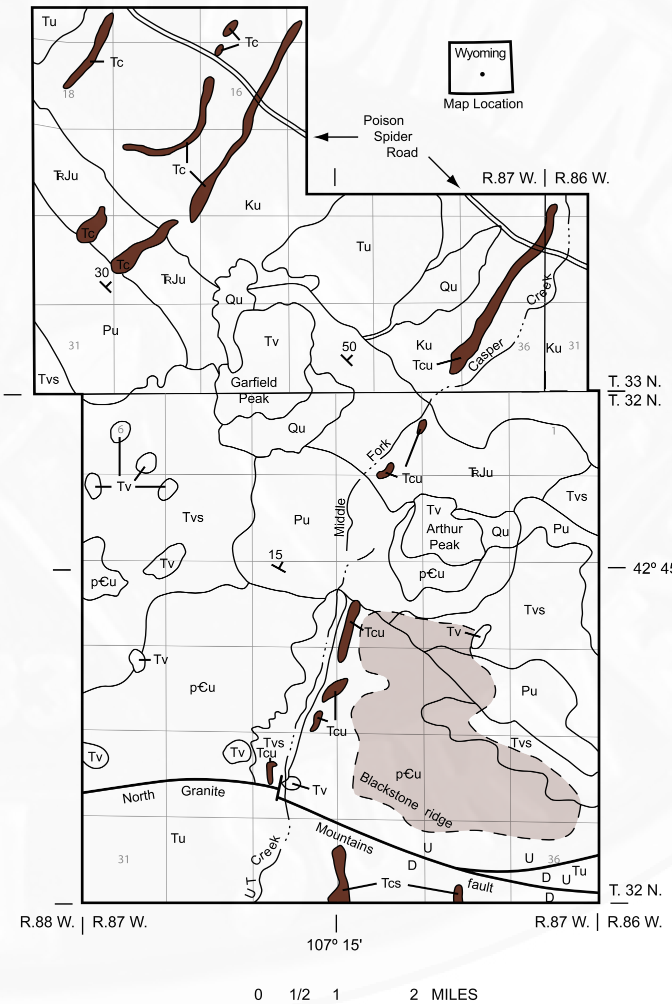

Figure 24. Generalized geologic map of the central Rattlesnake Hills showing the paleo-stream channel deposits (after Pekarek, 1974). Dark-brown areas are Tertiary channel deposits, including Southern set (Tcs) (Plio-Pleistocene), Northern set (Tc) (Oligocene), and UT Channel (Tcu) (Oligocene). Light-brown screened area is approximate extent of the Blackstone surface. Other abbreviations include Quaternary undifferentiated (Qu), Eocene volcanics undifferentiated (Tv), Eocene volcanic sediments (Tvs), Tertiary undifferentiated (Tu), Cretaceous undifferentiated (Ku), Triassic-Jurassic undifferentiated (ꞦJu), Paleozoic undifferentiated (Pu), and Precambrian undifferentiated (p€u).

cene and a southern set dated as Pliocene and Pleistocene (Plio-Pleistocene). The northern set, present in a series of curvilinear ridges developed on the Wind River Formation and Cody Shale on the northeastern flank of the Rattlesnake Hills (**Figures 24** and **25**), appear to be similar to, but smaller than Polecat Bench in the Bighorn Basin (Mackin, 1937; 1947). These northern ridges, containing unsorted, bouldery stream deposits (Tc on **Figure 24**), are topographically inverted. Stream channel deposits formed in topographic lows now cap interstream divides. In a few instances, the stream deposits can be traced discontinuously southward into the Rattlesnake Hills.

The best preserved example of channel deposits, produced by a paleo-stream, herein called UT Channel (UTC), parallels UT Creek and Middle Fork Casper Creek from the SW NW section 28, T32N, R87W, northeastward to the SW section 19, T33N, R86W, a distance of eight miles (**Figures 24** and **25**). The extensive outcrop of UTC deposits in W1/2 SE section 21, T32N, R87W, overlies hornblende schist and contains abundant granite gneiss and hornblende schist boulders with maximum dimensions of six feet and two feet, respectively (**Figure 26**). Cobbles and small boulders (up to 15 inches in diameter) of white quartz are common. Farther south, small remnants of UTC deposits in the SW NW section 28, T32N, R87W, are discontinuous and have similar-sized boulders of granite gneiss, hornblende schist, and quartz. The only reasonable source for the granite gneiss boulders is the Granite Mountains to the south which are now topographically lower than the channel deposits, implying that a drainage reversal has occurred in the southern Rattlesnake Hills. Earlier stream flow had to be to the north-northeast whereas UT Creek now flows southward.

Figure 25. UT channel deposits capping a narrow ridge of Wind River strata lying across Cretaceous rocks on the northeastern flank of the Rattlesnake Hills are outlined by the dashed line. View is to the southwest. The south end of the channel is in the SE section 35, T33N, R87W, and the Middle Fork Casper Creek is on the left (southeast) side of the ridge.

Figure 26. Contact of the UT channel deposits with the underlying Precambrian metagraywacke (hornblende schist) in the foreground. The outcrop is on the ridge top in the W1/2 SE section 21, T32N, R87W. The hammer is resting against a boulder of granite gneiss. Larger granite gneiss boulders are on the horizon in the upper right, darker boulders are hornblende schist.

The lithology of the boulders and cobbles in the UTC deposit changes systematically to the north as outcrops of Paleozoic and Mesozoic strata are crossed. Boulders of each lithology progressively decrease in size and increase in rounding to the north with distance from the source outcrops. Cobbles of quartz latite of the type present in Garfield and Arthur Peaks are abundant in the channel deposits north of these peaks (**Figure 24**). This systematic change in lithology and the progressive decrease in clast size also indicate stream flow to the north.

Although no attempt was made in the field to trace the UTC deposit into the Wind River Basin beyond SW section 19, T33N, R86W, topographic maps contain no obvious linear ridges suggesting topographically inverted channel deposits beyond this point. At the north end, the UTC deposit contains cobbles and occasionally small boulders (less than 15 inches in diameter) of Flathead and Tensleep quartzitic sandstone, cobbles (and rarely small boulders) of quartz latite, Madison Limestone, granite gneiss, and hornblende schist. Roughly half of the cobbles are quartzitic sandstone, and 40 to 50% of the pebbles are quartz latite. All boulders and cobbles are sub-angular to subrounded. The matrix is medium reddishgray and appears to contain debris from the redbeds of the Triassic Chugwater Group.

. . .the central part of the Granite Mountains subsided a minimum of 3200 feet relative to the Rattlesnake Hills.

Gravel-capped broad benches beveled at two or more levels on the Split Rock Formation (Tu on **Figure 24**) south of the North Granite Mountains fault appear to be remnants of pediments. A good example is found in the NE section 4, T31N, R87W. The gravels are thin and contain abundant pebbles and small cobbles of hornblende schist. Parts of these benches and some separate curvilinear ridges are capped by bouldery channel deposits (Tcs on **Figure 24**) containing abundant small boulders of hornblende schist, occasional cobbles of white quartz, and rare small boulders of coarse-grained sandstone, possibly from the Cambrian Flathead Formation. Source areas for these lithologies indicate that these channel deposits result from southward-flowing streams originating in the Rattlesnake Hills north of the North Granite Mountains fault (**Figure 27**). In some areas, several generations of channel deposits at different elevations have been produced by the same stream as illustrated by the benches originating in the NW NE NE section 33, T32N, R87W (**Figure 27**). As these benches now form ridges, topographic inversion has taken place. These stream deposits are referred to as the southern set to conveniently distinguish them from stream deposits of the northern set described earlier.

Ages of channel deposits

The southern and northern sets of stream deposits are of different ages with the southern set being younger than the northern set. The southern set must be younger than the early-to-middle Miocene Split Rock Formation on which they formed and is younger than the downfaulting and subsidence of the Granite Mountains that caused a reversal of stream gradients from north-flowing to south-flowing. The lithology of the coarse clastics requires deposition by southward-flowing streams. Consequently, the southern channel deposits are probably Plio-Pleistocene in age.

Figure 27. The Blackstone surface in sections 22, 23, 26, and 27, T32N, R87W. View is to the northeast. The surface is cut on Precambrian metamorphic rocks, Cambrian formations, and the Eocene Wagon Bed Formation north of the North Granite Mountains fault line scarp, which extends left to right across the center of the photo. Several benches cut on the Split Rock Formation and armored in part by paleo-stream channel deposits are present in front (south) of the fault line scarp.

The deposits of UTC contain clasts of quartz latite of the variety found at Garfield Peak and must, therefore, be younger than the early late Eocene age of the quartz latite (Pekarek and others, 1974). Clasts of granite gneiss probably had a source in the Granite Mountains to the south and must have been transported prior to the reversal of drainage produced by the subsidence of the Granite Mountains starting in early Miocene (Love, 1970). Consequently, the northern deposits, including those of UTC, are thought to be primarily of Oligocene age.

High level erosion surface

The large area of Precambrian hornblende schist exposed on Blackstone ridge (informal name) in the central part of the Rattlesnake Hills (**Figures 24** and **27**) is beveled by a roughly planar erosion surface, the Blackstone surface. This surface slopes gently to the south and ranges in elevation between 7600 and 8000 feet. The most extensive and undissected part in sections 22, 23, 26, and 27, T32N, R87W (**Figures 24** and **27**) slopes to the south at 50 feet per mile (0.5°) (Pekarek, 1978, Plate 1). The Blackstone surface is thought to be a "subsummit" surface (Mackin, 1947, p. 107-109) rather than a "summit" surface.

Valleys cut in rocks underlying the Blackstone surface contain strata of the middle and late Eocene Wagon Bed Formation. In some instances (e.g., SE section 22, T32N, R87W, and NE section 26, T32N, R87W), Wagon Bed strata form part of the surface (Pekarek, 1978, Plate 1). Mackin (1947, p. 107), in discussing the similar subsummit surfaces of the Bighorn and Laramie mountains, stated "alluvial-filled valleys below the level of the surface prove that valley cutting and aggradation preceded the period of planation." Consequently, the Blackstone surface is interpreted to be younger than the middle-to-late Eocene Wagon Bed Formation. The Blackstone surface is cut by and, therefore is older than the post-middle Miocene movement on the North Granite Mountains fault (Love, 1970). The resulting age limits on the Blackstone surface are late Eocene to early Miocene (essentially Oligocene), a time of crustal stability in central Wyoming (Love, 1970). The Granite Mountains were high in that time interval indicating that the Blackstone surface originally sloped northward. This age bracket is the same as that of the northern set of paleo-stream deposits and may be at least partially contemporaneous with the post-Laramide, late Eocene erosion surface in the Southern Rocky Mountains Province (Epis and Chapin, 1973).

Tectonic significance

The development of the Blackstone surface and of the two sets of paleo-stream deposits agrees with and confirms the tectonic history given by Keefer (1970) and Love (1970). The drainage reversal provides striking evidence for the late Cenozoic subsidence of the Granite Mountains. An estimate of the amount of subsidence in the Granite Mountains can be derived from postulated initial characteristics of the Blackstone surface that originally sloped to the north and underwent a reversal of slope, probably during the subsidence of the Granite Mountains that started in Miocene time. Independent evidence of this regional warping is found in the vicinity of the Gas Hills uranium district, where the originally northward-dipping Wind River Formation now dips south (Soister, 1968, p. 2, p. 7; Love, 1970, Plate 6-B). Similarly, the Split Rock strata capping the buttes in sections 7, 17, and 18, T32N, R87W (not shown on **Figure 24**), dip 8 to 10° southward, probably representing at least some southward tilting of these strata that had a nearly horizontal original dip (J.D. Love, personal communication, 1970).

The Blackstone surface probably reached its maximum development just before the Granite Mountains began to subside in Miocene time (Love, 1970, p. 122). The surface probably extended as much as 12 miles south of the present remnant in the Rattlesnake Hills to the line of granite knobs between McIntosh Peak (T29N, R89W) and Savage Peak (T29N, R87W). This extended surface, cut on Precambrian granite and granite gneiss, may be preserved under the present cover of the Miocene Split Rock Formation in the area between the North Granite Mountains fault and the granite knobs to the south.

If the Blackstone surface does exist under Tertiary cover in the Granite Mountains graben, a postulated original gradient for the surface can be used to approximate the amount of subsidence of the Granite Mountains in the late Tertiary. Similar erosion surfaces exist on other ranges of the Rocky Mountains such as the surfaces in the Uintas described by Bradley (1936) and the surface in the Southern Rocky Mountains (Epis and Chapin, 1973). As a first approximation, the gradient given by Bradley (1936) for the Gilbert Peak surface is extrapolated to the extended Blackstone surface and used to estimate the pre-subsidence elevation of the Granite Mountains relative to the Rattlesnake Hills. Bradley (1936, p. 174) gave the average gradients of the Gilbert Peak surface for each five-mile increment from the crest of the Uintas north into the Green River Basin. The gradients vary from 400 feet per mile (4.3°) near the crest of the Uintas to 55 feet per mile (0.6°) at a distance of 30 to 35 miles. Using these gradients and assuming that the area north of Savage Peak represents the southernmost and originally highest extent of the Blackstone surface, the south edge of the surface would have been about 1700 feet higher than the exposed surface in the Rattlesnake Hills.

The presumed buried surface in the vicinity of Savage Peak is now at an elevation of 6500 feet or less, depending on the depth of burial by the Split Rock Formation, whereas the Blackstone surface is as high as 8000 feet in the Rattlesnake Hills. This elevation difference of 1500 feet plus the 1700 feet of rise due to the probable gradient of the surface means that the central part of the Granite Mountains subsided a minimum of 3200 feet relative to the Rattlesnake Hills. This agrees with the amount of subsidence determined from stratigraphic data by Love (1970, Plate 6-D). At least 1000 feet of this subsidence can be accounted for by the late Cenozoic movement on the North Granite Mountains fault system (Love, 1970, p. 109; Pekarek, 1977). The remaining 2200 feet of subsidence probably results from regional warping that produced the reversals of slope from north to south on the Blackstone surface in the Rattlesnake Hills.

This estimate of 3200 feet of Late Cenozoic subsidence of the Granite Mountains supports the existence of a high mountain range in central Wyoming during the middle of the Cenozoic as originally determined by Love (1970). Presently, the highest peak in the Granite Mountains is McIntosh Peak at 8058 feet. Adding 3200 feet to 8058 feet indicates a mountain range with peaks possibly in excess of 11,000 feet, depending on the regional elevation of central Wyoming in earliest Miocene time. Love (1970, Plate 10) diagrammatically shows the history of this high mountain range, the Ancestral Granite Mountains, extending from the Shirley Mountains on the east to the Long Creek arm of the Wind River Basin on the west, a distance of nearly 100 miles.

Summary and conclusions

The geomorphic data of the present study agree with and confirm the Cenozoic tectonic history detailed by Love (1970). The UTC deposits of Oligocene age and related channel deposits on the north flank of the Rattlesnake Hills document the elevation of the Granite Mountains at that time. The Blackstone surface was beveled at that time. The subsequent collapse of the Granite Mountains led to drainage reversal and a second and younger set of paleo-channel deposits extending southward from the Rattlesnake Hills.

Acknowledgements

I would like to thank the ranchers in the Rattlesnake Hills for their hospitality.

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*New releases since *Wyoming Geo-notes No. 77* (June, 2003).

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The Wyoming State Geological Survey (WSGS) is proud to announce they are now an official dealer of maps and related products published by National Geographic Maps (NGM), a division of the National Geographic Society. The WSGS plans to carry a limited supply of all the National Geographic maps relating specifically to Wyoming as well as some selected regional maps. These products are available by mail or over-the-counter at the WSGS publications sales office in Laramie; add sales tax (where applicable) and shipping and handling (see order form for details). Listed below are the maps and other products that we presently carry.

Reference and wall maps

World Political Classic (multi-color), scale 1:38,931,000, size 43″ x 30″ rolled only - $12.99.

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World Political Executive (brown antique style), enlarged, scale 1:20,977,000, size 73″ x 49″ rolled only - $29.99.

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Yellowstone NE/Tower/Canyon, scale 1:83,333, folded only (ISBN 0-92587-374-8) - $7.95.

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Travel Guides—Close-Up USA™ maps

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TOPO!™ PC version

TOPO!™ Wyoming, CD-ROMs for all Wyoming 1:24,000-scale maps (ISBN 0-7922-8411-9) - $99.95.

Pocket TOPO!™ PC Only, Transfers state series TOPO! Maps to Palm or Pocket PC PDAs, (ISBN 0-7922-3358-1) - $24.95.

USGS publications

We have a limited number of several out-of-print U.S. Geological Survey (USGS) professional papers and bulletins. Available only while supplies last; sales tax and shipping and handling charges also apply (see order forms for details).

USGS Bulletin 1911, Sedimentology of freshwater lacustrine shorelines in the Eocene Scheggs Bed of the Tipton Tongue of the Green River Formation, Sand Wash Basin, northwest Colorado, by H.W. Roehler, 1990, 12 p., 1 pl. - $1.00.

USGS Bulletin 2018, Geological investigations of the Wamsutter Rim canneloid coal bed in the Eocene Niland Tongue of the Wasatch Formation, northern Washakie Basin, Wyoming, by H.W. Roehler and R.W. Stanton, 1992, 16 p., 1 pl. - $1.00.

USGS Professional Paper 1506-A, Introduction to greater Green River Basin geology, physiography, and history of investigations, by H.W. Roehler, 1992, 14 p., 1 pl. - $2.00.

USGS Professional Paper 1506-B, Revised stratigraphic nomenclature for the Wasatch and Green River Formations of Eocene age, Wyoming, Utah, and Colorado, by H.W. Roehler, 1991, 38 p. - $2.00.

USGS Professional Paper 1506-C, Godiva Rim Member—A new stratigraphic unit of the Green River Formation in southwest Wyoming and northwest Colorado, by H.W. Roehler, 1991, 17 p. - $2.00.

USGS Professional Paper 1506-E, Correlation, composition, areal distribution, and thickness of Eocene stratigraphic units, greater Green River Basin, Wyoming, Utah, and Colorado, by H.W. Roehler, 1992, 49 p., 1 pl. - $3.00.

GIS Update

Joseph M. Huss

GIS Coordinator–Publications, Wyoming State Geological Survey

The geographic information systems (GIS) group at the Wyoming State Geological Survey (WSGS) continues to grow as mapping projects now demand digital products. The staff now includes three full-time personnel, one graduate student, two contract GIS specialists, and an intern. Current projects branch across all of the geologic sections at the WSGS and contain a wide (and challenging) variety of geologic and mineral resource data. There are a number of digital maps being produced, as described below. Additionally, an Internet Map Serving (IMS) site is being developed in cooperation with the Geologic Hazards Section, infrastructure and future planning is coordinated with the

Information Technology Section, and the WSGS is aiding the State of Wyoming in coordinating GIS activities.

STATEMAP 2003

A subproject of the WSGS grant for STATEMAP 2003 is underway with the digital compilation and development of four 1:100,000-scale bedrock geology maps and two 1:100,000-scale surficial geology maps. The bedrock geology maps include Evanston, Kemmerer, Kinney Rim, and Nowater Creek; the two surficial geology maps are Chugwater and Nowater Creek. All the geology has been digitized and is being reviewed and edited. Some of the cartographic layouts are in progress. A detailed discussion of this project was presented in the Geologic Mapping, Paleontology, and Stratigraphy Update in *Wyoming Geo-notes No. 77*, June, 2003.

Love Map Series

The publications and GIS staff are continuing work on six 1:24,000-scale quadrangles for the WSGS Love Map Series (LMS). These inlcude Jackson (LMS-9), Colter Bay (LMS-10), Moran (LMS-11), Jenny Lake (LMS-12), Davis Hill, and Whetstone Mountain. The geology and cartographic layouts for the first four of these maps are in final edit and review. LMS-1 through LMS-8 were previously completed. This series will ultimately contain 45 1:24,000-scale quadrangle maps covering most of Teton County in both hard copy and digital formats.

Graduate assistantships

Justin T. Carreno, our first graduate assistant (GA) with the Department of Geography and Recreation, University of Wyoming (UW) completed compilation of a 1:250,000-scale, digital bedrock geologic map of northeastern Wyoming. This map includes the Gillette, Newcastle, Sheridan, and Arminto 1:250,000 quadrangles (see *Wyoming Geo-notes No. 78*, November, 2003, p. 34-35). The map will augment digital coverages at a scale of 1:100,000 that are already completed or in progress and fill in those areas where digital coverage does not exist. The Publications Section is finishing the explanation and cartographic layout for publishing this map in hard copy and digital release. Meanwhile, Justin Carreno is writing his thesis and preparing his defense to achieve an M.A. degree in Geography.

In September, 2003, David W. Lucke, our second GA with the Department of Geography and Recreation at UW began compilation of the 1:250,000-scale digital bedrock geologic map of southwestern Wyoming. It includes the 1:250,000-scale Lander, Ogden, Preston, and Rock Springs quadrangles. Compilation of the data will be completed by the end of Summer, 2004.

The assistantship program will continue with compilation of 1:250,000-scale quadrangles in southeastern Wyoming beginning in the Fall, 2004. Compilation of a digital geologic map of northwestern Wyoming will commence in the Fall, 2005.

State coordination

Joseph M. Huss presently chairs the Wyoming Geographic Information Advisory Committee (WGIAC). Additionally he is leading the development of a new statewide GIS coordination plan. Both activities aid the State of Wyoming and the WSGS in coordinating, developing, and sharing geospatial data. The plan should aid in saving the State money yet increase coordination of projects and data development.

WSGS receives GIS award

The WSGS received the Special Achievements in GIS (SAG) Award from Environmental Systems Research Institue (ESRI®) in July, 2003. The award was given for overall GIS integration for the WSGS, including GIS development, coordination, and implementation. The award was based in part on spatial data collection, library development, Spatial Data Engine (SDE), transitioning, development of new data, new and existing projects, inter- and intra-agency cooperation, and new GIS internships and graduate assistantships.

The award was presented by Jack Dangermond, founder and president of ESRI®, along with ESRI® Wyoming representative Jeff Garland. The SAG award information may be viewed at http://www.esri.com/sag/index.html under 2003, Wyoming State Geological Survey.

Annual ESRI Southwest Users Group

GIS personnel from the WSGS conducted registration and participated in the Annual ESRI® Southwest Users Group (SWUG) meeting. The event was held in Jackson October 27 through 30, 2003 with over 200 attendees from a variety of states. The conference focused on natural resource management, planning and legal issues, imagery, and government.

GIS courses

The WSGS continues its outreach efforts in GIS education with two ESRI® courses, *Introduction to ArcGIS I* and *Migrating from ArcView 3.x to ArcView 8.* These courses are taught in conjunction with the Wyoming Geographic Information Science Center (WyGISC) at UW. Joseph M. Huss, an ESRI® certified instructor, continues this cooperative effort to further GIS knowledge and use of geospatial data in Wyoming.

Joe instructed *Introduction to ArcGIS I* in August, 2003; November, 2003; and March, 2004. Information on these courses can be found on the WyGISC web site (http://www.wygisc.uwyo.edu/education.html) or by contacting Joseph M. Huss at (307) 766-2286 ext. 234 or jhuss@uwyo.edu.

Staff Profile: Fred H. Porter

Richard W. Jones, Wyoming PG-2972

Editor/Senior Geologist–Publications, Wyoming State Geological Survey

The Wyoming State Geological Survey (WSGS) will lose one of its most experienced draftsmen/cartographers on July 1, 2004, when Fred H. Porter retires after 28 years of service. Fred (**Figure 28**) has been the Survey's senior illustrator, cartographer, and GIS specialist for a number of years, being responsible for producing many of the WSGS maps, charts, and other graphics used in publications.

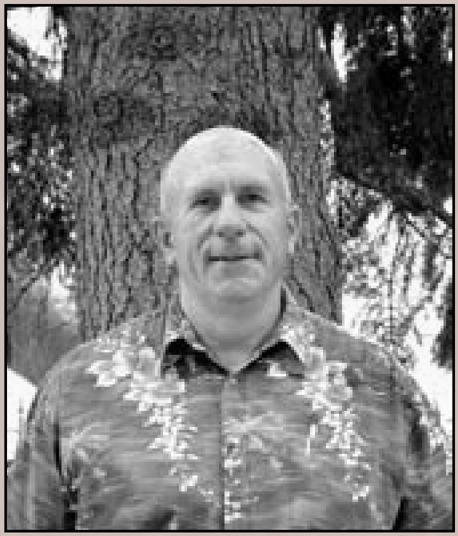

Figure 28. Fred H. Porter is a cartographer and GIS Specialist at the Wyoming State Geological Survey. Photograph by Jaime R. Moulton.

Fred is one of few Wyoming natives at the WSGS; he was born and raised in Cheyenne. He attended Cheyenne schools and graduated from Cheyenne East High School in 1965. He went on to the University of Wyoming in Laramie, where he earned a B.A. degree in Art with a minor in Business in 1973. He joined the WSGS in 1976 as a Draftsman/Illustrator/Cartographer, the same year that the Survey moved into their new building. Fred has probably aged less than the building!

His first few years at WSGS were spent on a variety of projects, learning the traditional methods and techniques of drafting and map-making that made them more an art form than just technical drafting. He remembers the considerable amounts of time that the large geologic maps took to complete, and any mistakes (such as spilling coffee on the scribe coat, embarrassingly in front of the author) could mean starting over from scratch. One of the first maps he completed as lead cartographer was a tectonic map of the western Wyoming Overthrust Belt by D.L. Blackstone. At the time, this map was extremely important to oil and gas exploration and development in the area; with each new version of the map in the 10 years that followed, it effectively documented (and certainly assisted with) oil and gas development in this province. Another map Fred worked on (but much later) was so complex that even after it had been printed, it still had to have a geologic map unit colored by hand. Unfortunately, we only seem to remember all the "maps from hell" and forget all the beautiful, artistic color maps that were made.

Fred made a conscious effort to improve the WSGS map-making capabilities, ranging from installing a darkroom, complete with vacuum frame and high intensity lights, to adapting a professional pin registration system and bi-angle screen system that was state of the art. Most of the equipment and facilities in our drafting department were hand-built and customized by Fred and anything purchased was done under very tight budget constraints. Our printed map products were second to none, due in large part to Fred's commitment to high quality and his creativeness in finding solutions to problems without spending any money.

During Fred's career with the WSGS, he has been involved with our transformation from Leroy® lettering and Rapidograph® drafting, hand scribing, and extensive darkroom work (using large format cameras, photographic processes, and wipe-on color proofs) to exclusively computer drafting and Geographic Information Systems (GIS). Since 1994, he had to relearn practically every aspect of his job as it applied to the new computer drafting and map-making methods. The transition was not easy, and ofttimes painful, since GIS was just in its infancy and the learning curves were rather steep. However, Fred met the challenge and has persisted despite being drawn into the computer age whether he wanted to or not.

Fred and his wife Elsie have been married since 1972 and they have two sons, David and Jerry, as well as two grandchildren. After Elsie retires from her job at Ivinson Memorial Hospital in Laramie a year after Fred retires, the couple plans to move to Salida, Colorado. They own and operate an RV park and campground (which has been an ongoing project for several years now), and they even plan to develop a bed-and-breakfast there someday. Fred hopes to catch and release a lot of fish in a somewhat pastoral retirement, and pursue his artistic talents by capturing landscape, scenery, and wildlife through paintings and watercolors. We wish Fred and Elsie the very best retirement, and hope Fred still encounters the "Cookie Monster" at appropriate times.

Everyone at the Survey will miss you Fred! Our best wishes go to you and your family!

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

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☹ Sorry, we do not accept credit cards for payment at this time.

Many Wyoming State Geological Survey publications are also available for purchase over-the-counter at the Wyoming Oil and Gas Conservation Commission office, 2211 King Boulevard, Casper, Wyoming 82602-2640.

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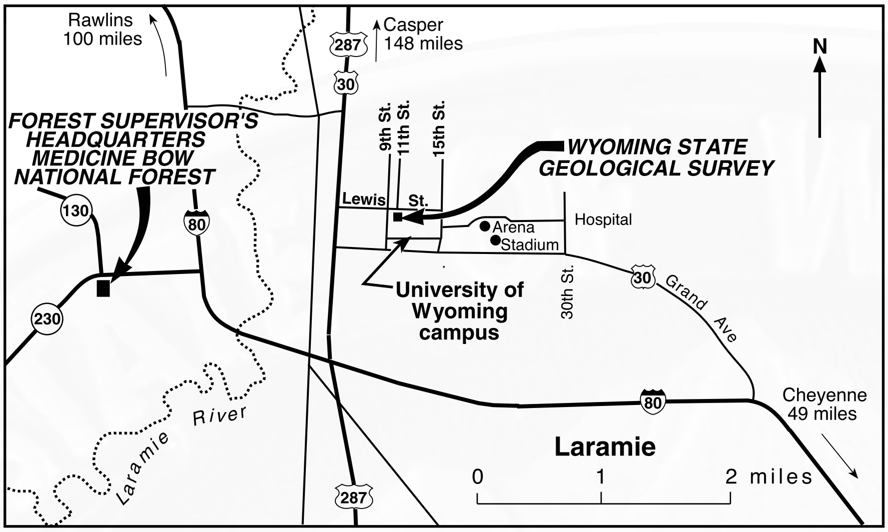
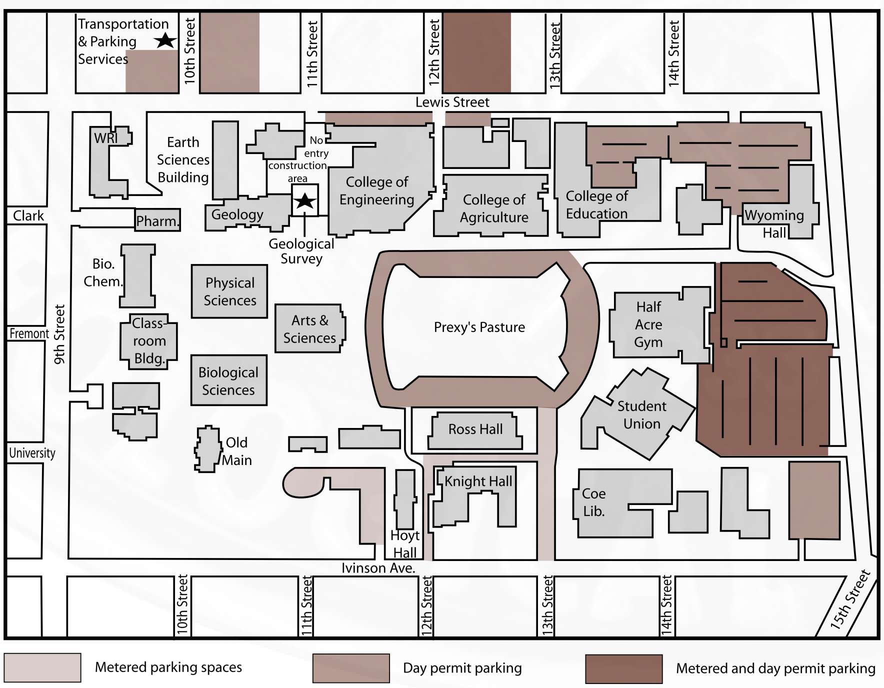
Please include shipping and handling charges and 6% Wyoming sales tax (if applicable). Insufficient payment will delay your order. Prices may change without notice. Please allow 2 to 3 weeks for delivery of your order. Some items may not be immediately available, in which case the WSGS will notify you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

Location Map for the Wyoming State Geological Survey





Parking options for the WSGS and the University of Wyoming campus

Metered Parking: Metered parking is available at various locations on campus to provide short-term parking. Meters are available at the following locations: Hoyt Hall, Knight Hall, Coe Library, Wyoming Union, Fine Arts, Corbett Gym, Arena-Auditorium, Beta House, 12th & Lewis, and Animal Science. The fee for metered parking is 25 cents per half hour.

Day Lot: The Day Lot is located at 15th and Willett Dr., south of Wyoming Hall. The fee for the Day Lot fee is 25 cents per half hour. An attendant staffs the lot from 8 a.m. to 8 p.m.

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Day Permits: Day permits are available from the Transportation & Parking Services department at 462 North 10th, Visitor Services Center, and the Wyoming Union Information Desk. The fee for a Day Permit is $4 per day and allows the permit holder to park in an "A", "C" or "R" space. Day permits may be purchased for multiple days. These permits can be purchased by anyone, including UW departments with an IDR.

City Streets: Parking may be found on some of the surrounding city streets. This parking is free, however some areas are reserved for resident permit parking only.

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