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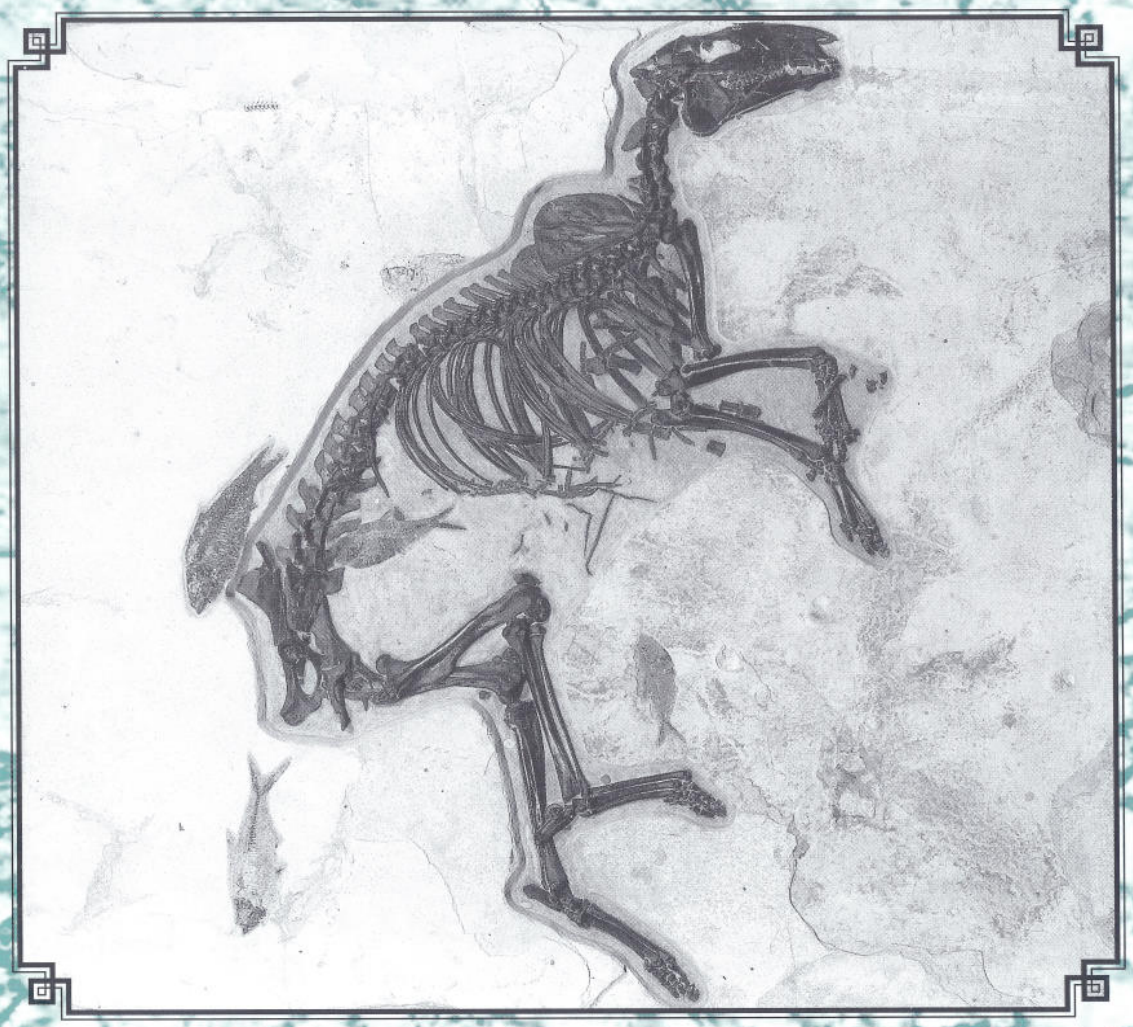

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Laramie, Wyoming
May 2005

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Front cover: This spectacular fossil of an early Eocene representative of the horse family was recently found by fossil collector Jim Tynsky of Kemmerer in the Green River Formation. The fossil has been identified by several paleontologists as the genus *Hyracotherium*, an early relative of the modern horse. It was found in 50-million-year-old rocks that were deposited in a shallow lake called Fossil Lake, the westernmost part of the large Eocene Lake Gosiute. How this animal got preserved in rocks that usually contain fossil fish and snails is still an ongoing topic of conversation. The "dawn horse" or Eohippus as it was once named, probably stood about 12 inches high at its shoulder and weighed about 40 or 50 pounds. Photography by Arvid Aase, Fossil Butte National Monument, U.S. National Park Service, used with permission.

THE FUTURE OF THE WYOMING STATE GEOLOGICAL SURVEY

Ronald C. Surdam, Wyoming PG-1546

State Geologist, Wyoming State Geological Survey

When I arrived at the Wyoming State Geological Survey (WSGS), it was at an important crossroads; it could remain relatively static and reactive, or it could become more dynamic and proactive. The WSGS chose to develop a plan to break from tradition and follow a new path that would result in a Survey capable of proactively assisting the state in overcoming a wide spectrum of natural resource challenges. The Governor endorsed the plan and the Legislature supported it through a supplemental appropriation. The WSGS now has a chance to prove its worth by becoming a more valuable asset to the state.

The plan is to make the WSGS more relevant to the natural resource issues Wyoming will face in the 21st century. The WSGS will be dedicated to becoming capable of assisting diverse state decision-makers in government, industry, and the public sector in making quality, informed decisions related to optimizing responsible natural resource development. This mission can be accomplished by providing all segments of Wyoming society with the highest quality, unbiased, reliable, and accurate geological and geophysical information attainable.

Another aspect of the plan is to provide interested parties living and operating in the state access to the latest and best available exploration technologies and development strategies. The additional investment in the WSGS will allow it badly needed flexibility to keep pace with the rapidly evolving technological and data requirements required to responsibly develop natural resources. One of the Survey's highest priorities will be to assist all operators with information transfer. If you need the Survey's help, you only need to ask!

The supplemental budget will add much needed expertise in geohydrology, geophysics, and geological/geophysical modeling and visualization to the WSGS. Equally important, it provides the Survey with the ability to add badly needed junior scientific positions to help insure orderly succession within the agency. With most of the present section leaders approaching retirement age, it is vital to retain as much of their expertise as possible through a mentoring system. The supplemental appropriation will also allow the WSGS to acquire the additional hardware, software, and data necessary to accomplish their expanded 21st century mission.

Acquisition of new expertise and retention of existing expertise and experience will further enable the Survey to maintain relevancy in the field of natural resources. A high priority Survey mission is to assist in developing the technologies, strategies, and diagnostic techniques that will be necessary in the future to maintain positive slopes on the state's energy and mineral production curves (e.g., positive growth of state revenues). In brief, integrating new assets with the existing competent staff will provide the residents of Wyoming with the kind of information and assistance vital in creating an optimum future in the 21st century.

The natural resource challenges facing Wyoming in the future will not be solved by individuals, but will be solved by relatively small, integrated teams of scientists with diverse interests, but common goals. The future of the WSGS will be characterized by problem definition, applied research, diversity of interest, common goals, teamwork, integration of expertise, and relevancy to those challenges.

In the future, the magnitude and rate of natural resource development in Wyoming will increase dramatically; the resulting challenges will rapidly increase in both diversity and magnitude. As the nation faces a deepening energy predicament, it will turn to those states with the ability to export energy. Importing 60% of utilized crude oil from foreign sources will become an ever-increasing national economic burden as energy prices continue to rise. As the Middle East and Venezuelan oil provinces approach maximum production and any of the world's excess oil production is consumed by expanding economies (i.e., China and India especially), the price of energy can only go up. As a consequence, energy-rich states such as Wyoming will receive more pressure to increase production of oil (through enhanced oil recovery projects), coal, conventional natural gas, basin-center natural gas, and coalbed natural gas.

At $35 per barrel for crude oil, both coal gasification and liquefaction become economic. Synfuels derived from oil shale probably become economic at $40 per barrel. With its huge coal reserves and oil shale resources, Wyoming is destined to be a major player in producing unconventional energy. The initiation of synfuel activity in Wyoming waits only for a demonstration that these threshold crude oil prices are stable. In addition, the price of uranium yellowcake increased from $9 per pound to $20+ per pound in 2004; so in the next decade, uranium mining in Wyoming will be revived as national interest in nuclear power returns. With respect to the national need for domestic energy sources, it is reasonable to assume that the nation will turn to Wyoming, the state that is presently the nation's leading energy producer.

Mining activity in Wyoming should increase dramatically in the next decade. For example, the huge diamond discoveries in Canada will result in further interest in known and yet undiscovered diamond localities in Wyoming. The geological

settings for the Wyoming diamond locations are very similar to those of the diamond discoveries in Canada. In addition, Wyoming has huge potential for major domestic copper, gold, silver, and other mineral commodities. Both mineral and energy resources in Wyoming will continually receive ever-increasing interest and development.

The questions of greatest importance to Wyoming are when, where, and how will its energy and mineral resources be developed, and what kinds of problems will accompany the development. These are the questions that the expanded, more proactive and better integrated WSGS can help to answer, not by looking back, but in a forward predictive mode. With the assistance of additional staff, data, equipment, and new leadership requested in the supplemental budget, the Survey will be able to move more effectively and efficiently to provide the state with reliable, unbiased, and accurate geological observations, interpretations, and models to answer the when, where, and how questions. Only by answering these questions and tackling the identified problems can the state be insured of responsible natural resource development that maximizes state revenues.

The WSGS is excited about the challenges of the 21st century, and is enthusiastic about the role it can play in the state's future. When in Laramie, please stop by and visit your state geological survey—we think you will be impressed.

STAFF PROFILE: RONALD C. SURDAM

Richard W. Jones, Wyoming PG-2972

Editor/Senior Geologist–Publications, Wyoming State Geological Survey

Dr. Ronald C. Surdam (**Figure 1**) is the new Wyoming State Geologist and Director of the Wyoming State Geological Survey (WSGS). He was first appointed as interim to the position by Governor Freudenthal in July 2004 following the resignation of Lance Cook, and received a permanent appointment by the governor in November 2004. He is the 15th State Geologist of Wyoming. Dr. Surdam brings an already distinguished geological career to the WSGS, accompanied by an international reputation and a proven track record in both academia and industry. The state and the WSGS are very fortunate to have a geologist of Dr. Surdam's caliber as State Geologist. Much of the following was abstracted or taken directly from Dr. Surdam's resume and vita; the present author takes full responsibility for any errors or omissions.

Ronald C. Surdam was born and educated in Los Angeles, California, culminating with an A.B. degree (Geology) in 1961 from the University of California, Los Angeles (UCLA) and the Ph.D. degree (Geology) in 1967, also from UCLA. He came to Wyoming to stay in 1966, joining the faculty of the Department of Geology and Geophysics at the University of Wyoming (UW) as an Instructor of Geology. He moved rapidly through the academic ranks as Assistant Professor, Associate Professor, and finally Professor of Geology in 1973. He served on the faculty for 32 years, officially retiring from teaching in 1998; he remains a Professor Emeritus at UW to this day.

During his professorship, Dr. Surdam also served as Director, Institute for Energy Research (IER) at UW from 1993 to 1998; he was named the I.E. Warren Professorship of Energy and the Environment at UW from 1994 to 1998; and was Director, Enhanced Oil Recovery Institute (EORI) at UW from 1997 to 1998. He also served as a Consultant to UW from 1998 to 2000, and in 2000 founded his own consulting firm, Innovative Discovery Technologies, LLC. He was President

Figure 1. Ronald C. Surdam is the newly appointed Wyoming State Geologist and Director of the Wyoming State Geological Survey. Photograph by Jaime R. Moulton.

of that company until July 2004 when he was named Interim Director of the WSGS and later in 2004 accepted his present appointment. He has been an Honorary Professor, University Nanjing, China since 2002.

In 32 years at UW, Dr. Surdam taught 16 different courses (including geologic mapping and field courses, stratigraphy, petrology and petrography, geochemistry, diagenesis, and paloelimnology) and directed 56 students to advanced

degrees. Seven of his students have won awards from professional societies for best papers or dissertations. In addition, he has taught numerous short courses and seminars for a variety of corporations and scientific societies around the world and has served as a consultant for numerous international energy and mineral exploration corporations. While at UW, he raised $32 million in research support through research grants and contracts from the National Science Foundation (NSF), U.S. Department of Energy (DOE), the State of Wyoming, the Gas Research and Gas Technology institutes, numerous oil companies, and private corporations. He has raised another $4 million in research funds since leaving UW.

Dr. Surdam founded and directed IER, a highly respected research group at UW dealing with problems relating to the exploitation of natural gas accumulations, elastic diagenesis, thermal modeling, source rock maturation, petrophysics, and pressure compartmentalization. IER had an annual budget of more than $2 million, supporting two faculty, four research scientists, two postdoctoral candidates, five graduate students, five department assistants, and eight staff positions. This multidisciplinary effort was constructed and supported exclusively by funding external to UW.

Under Dr. Surdam's guidance, IER developed a strong research reputation and received international recognition; he developed research interests in the San Joaquin and Coastal Basins of California, the Gulf Coast, Western Canadian Basin, and a variety of Rocky Mountain Laramide basins. Outside North America, he developed research interests in the Potiguar Basin of Brazil, the Mahakam Delta of Indonesia, the Gippsland Basin of Australia, the Roconcavo Basin of Brazil, the San Jorge, Neuquen and the offshore Colorado Marina basins of Argentina, and the Sinu Basin of Columbia.

While at UW, Dr. Surdam later served as Director of EORI, an integral unit of UW dealing with enhanced oil recovery techniques, including reservoir simulation, mathematical modeling, experimental studies, reservoir characterization, field studies, environmental studies, and economic analysis. In addition, he served UW in the following capacities during his career:

1. Chairman of President's Committee to prepare procedures to evaluate University of Wyoming Administrators.
2. Member of the Enhanced Oil Recovery Institute Advisory Committee.
3. Appointed to the Steering Committee of the University of Wyoming National Park Service Research Center.
4. Appointed to University of Wyoming Centennial Committee on Statewide Relations.
5. Member of the Western Research Institute Advisory Committee.
6. Member of the Wold Chair Selection Committee.
7. Consultant to Vice-President of Research (Director of the Jonah Gas Field Project) 1998 to 2000.

The focus of Dr. Surdam's scientific research and industrial activities during the last 38 years always has been oil and gas exploration, oil shale and trona depositional systems, and coal and zeolite deposits in the Rocky Mountain Laramide basins of Wyoming and adjacent states. He has done geologic field work in nine U.S. states, two Canadian provinces, Mexico, Japan, New Zealand, Australia, Africa (Kenya and Tanzania), Brazil, Indonesia, and Argentina; he has also lead numerous field trips to the Green River Formation of Wyoming (**Figure 2**), Colorado, and Utah, and the Monterey Formation in California. Needless to say, he has a great deal of experience in oil and gas exploration and in industrial minerals in a wide variety of sedimentary basins from around the world.

Figure 2. Dr. Surdam, left center, with baseball cap, leads a recent field trip to the Green River Basin to examine the depositional environments of early Eocene rocks. Photograph by Mario Slavinec, September 2004.

Surdam and coauthors have published nearly 200 articles in refereed scientific journals and books. He has presented 195 invited lectures and he and his students have given over 180 presentations at scientific meetings. Invited lectures include presentations in England, Scotland, Japan, Indonesia, Australia, New Zealand, Brazil, Venezuela, Canada, Argentina, China, Vietnam, Thailand, Brunei, Malaysia, and Kenya.

Dr. Surdam has not just served the state's university. Besides his activities at UW, he has served the State of Wyoming in a number of capacities (all gubernatorial appointments):

1. Member of Governor's Oil Shale Advisory Committee (1972 to 1973).
2. Member of the Wyoming Environmental Quality Council (1975 to 1983).
3. Member of Governor's Task Force on Land Use and Environmental Impact of Coal Development (1977).
4. Appointed to Governor's Select Committee to Study Acid Rain in Wyoming (1984 to 1985).
5. Appointed to the Wyoming Water Quality Board (1987).

6. Appointed to the Science, Technology & Energy Authority (STEA) Board (1995), Chairman of the STEA Board (1996 to 1997).
7. Appointed to chair the Department of Environmental Quality Permitting Task Force (Review and Evaluation of the National Pollutant Discharge Elimination System Permitting Process), 2004.

Throughout his career, Dr. Surdam has received 54 honors and awards. Most notable amongst these are the following:

1. Selected to serve on the National Science Foundation Geology/Geochemistry Advisory Panel (1980 to 1983).
2. Invited to address the Royal Society of London (1984).
3. Selected as an American Association of Petroleum Geologists Distinguished Lecturer (1985 to 1986).
4. Selected to serve on the American Chemical Society Advisory Panel (PRF) (1988 to 1993).
5. Elected a Fellow in the Geological Society of America (1989).
6. Appointed Associate Editor, Bulletin of the Geological Society of America (1989).
7. Appointed to the U.S. Continental Scientific Drilling and Review Group (1990).
8. Elected to present a series of Lectures as the Don R. and Patricia Boyd Distinguished Lecturer in Petroleum Exploration, University of Texas, Austin (1990).
9. Elected to receive the University of Wyoming President's Achievement Award (1992).
10. Chosen for Extraordinary Merit in Research, College of Arts and Sciences, University of Wyoming (1992).
11. With Leta Smith and T.L. Dunn, received the SEPM Excellence of Oral Presentation Award for presentation of the paper "Cation Geothermometry and the Effect of Organic-inorganic Diagenetic Reaction," (1994).
12. Received award for exemplary academic leadership in directing the two 1993 Outstanding Dissertation Awards of L.K. Smith and M. Garcia-Gonzalez's dissertations in the Physical, Earth, and Computational Sciences at the University of Wyoming (1993 to 1994).
13. Elected to receive the J.E. Warren Professorship of Energy and the Environment, University of Wyoming (1994).
14. Selected as the 1995-96 AAPG Roy M. Huffington International Distinguished Lecturer (1995).
15. Selected to receive the Frank A. Morgan Sr. Memorial Award for meritorious achievements and contributions in geology by the Wyoming Geological Association (1995).
16. Selected to receive the Robert H. Dott, Sr., Memorial Award for Best Special Publication published by AAPG in 1997 as follows: AAPG Memoir 67, *Seals, Traps, and the Petroleum System*, edited by R.C. Surdam (1999).
17. Elected Honorary Professor, University of Nanjing, China (2002).

Along with his administrative and scientific duties as Director of the WSGS and as State Geologist (he serves by statute on several state boards, commissions, and committees), Dr. Surdam continues to pursue a number and variety of research interests. He lists the following groups of topics as creative work in progress (but not in any particular order):

1. The depositional environment of the Green River Formation; a chemical model for the genesis of authigenic silicates in saline and/or alkaline lakes; the origin of oil shale and trona; and the geochemistry of zeolites.
2. Diagenesis of clastic sediments; diagenesis of the Monterey Formation; and the relationship between clastic diagenesis and hydrocarbon migration.
3. The role of mineral oxidants and organic solvents in enhanced porosity; prediction of enhanced and/or preserved porosity/permeability in hydrocarbon reservoirs; and integrated diagenetic maturation modeling—a process-oriented approach for clastic systems.
4. Processes causing the formation of pressure compartmentalization during progressive burial; origin of tight gas sands; exploitation of anomalously pressured gas accumulations; and exploration strategies for "basin-center" gas accumulations.
5. The integrated study of petroleum systems.

Dr. Surdam is a Registered Professional Geologist (PG-1546) in the State of Wyoming,. He is an active member of a number of professional and scientific organizations, including the Geological Society of America (GSA) (Fellow), American Association of Petroleum Geologists (AAPG), Society for Sedimentary Geology (SEPM), Sigma Xi, Wyoming Geological Association (WGA), Society of Petroleum Engineers, and the Association Latino Americana de Geoquimica Organica Alago.

Since he joined the WSGS last July, Dr. Surdam has been working tirelessly to raise the agency's profile, increase its role in exploration, development, and conservation of the state's mineral and geologic resources, and secure additional funds to accomplish this. The WSGS already has new goals, new positions and employees, supplemental funds, and a new outlook since his arrival. His vision for the WSGS is outlined in his article *The future of the Wyoming State Geological Survey* that appears on page 1 in this issue of *Wyoming Geo-notes*.

"Ron" as most of his friends and associates know him (even though if you were one of his students you still call him "Dr. Surdam"), has been married to his wife Joy for almost 40 years. They have three grown children, Jonathan, Daniel, and Mary-Katherine. His hobby is competitive field trialing, which as Ron explains, involves "training bird dogs and riding horses, all at the same time." He raises and trains English Pointers and maintains a horse stable; needless to say, he does not live in town. When in the office or in the field, he is known for his story telling, his wry sense of humor, and the (usually) good-natured ribbing he doles out.

GEO-NOTES FORMAT CHANGING

We are revising the way we offer *Wyoming Geo-notes*. After issues 81 and 82 are published, the traditional Mineral Update articles in *Wyoming Geo-notes* will be discontinued as part of the printed version, and offered instead via an Email subscription or online over the WSGS web site. The printed publication will be issued twice a year instead of quarterly and will contain only a year-end overview of significant mineral activity.

The mineral updates for oil and gas, coal, coalbed methane, industrial minerals and uranium, and metals and precious stones will continue to be offered every quarter, but only in electronic format. Since these will not be printed, they will be issued in a timelier manner. All the traditional graphs and tables for production and prices will be retained, as will the exploration activity graphs, activity and leasing maps, and other information currently included in the printed version. Some of the tabular data on spreadsheets will be available for download. Readers will have the option of receiving all the mineral updates or just the updates that they specify. There will be no charge for any of these new quarterly update subscriptions.

Wyoming Geo-notes will continue to be published twice a year, but will focus on activities and projects at the WSGS and provide more reports on various aspects of Wyoming geology and mineral resources. The new *Wyoming Geo-notes* will include updates and articles on geologic hazards, geologic mapping, and GIS that appear in our current issues. We hope to publish additional short articles by WSGS authors as well as outside authors, and we invite our readers to submit articles to us for consideration. We anticipate using full color graphics and photographs and hope to make the new *Wyoming Geo-notes* more a newsletter about the WSGS and the state's geology and minerals.

New and renewing subscribers to *Wyoming Geo-notes* will be notified about these new options and will be able to receive the free quarterly updates. The new semi-annual *Wyoming Geo-notes* will be available by subscription for a minimal fee. Those subscribers who have paid past *Wyoming Geo-notes No. 82* will continue to receive the printed version through the final issue that has been paid. Please fill out the order form below. The entire page can then be cut out, folded, and sent to us. Please do not include payment for *Wyoming Geo-notes* at this time, as we have not determined what the new subscription price will be.

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MINERALS UPDATE

Overview

Richard W. Jones, PG-2972

Editor/Senior Geologist, Wyoming State Geological Survey

This is our final Overview and Minerals Update in the present format of *Wyoming Geo-notes*. As explained in our last issue (*Wyoming Geo-notes No. 81*, November 2004), the individual articles in the Minerals Update will now be offered via Email subscription or online from the web site of the Wyoming State Geological Survey (WSGS). We will continue to publish *Wyoming Geo-notes*, but only twice a year with a different format and somewhat different content. To subscribe to any or all future mineral updates for oil and gas, coal, coalbed methane, industrial minerals and uranium, and metals and precious stones, we have included an order form and a description of our new formats on page 5. The next mineral updates will be available in June 2005 and the next printed *Wyoming Geo-notes* will be published this coming fall.

Mineral activity in Wyoming during the second and third quarters of 2004 continued at a record pace or at a pace close to that in 2003. For a detailed discussion and analysis of this activity, refer to the individual update articles for each mineral commodity. Continued high prices for energy minerals throughout the year and strong demand, especially for natural gas and coal, spell good news for Wyoming producers and the State of Wyoming. Production of natural gas and coal through three quarters was up nearly 3% and 6%, respectively, over the same period in 2003; by year's end, both commodities will exceed 2003's production by over 5%. The average price for natural gas is significantly higher (over 15%) in 2004 than in 2003 and the average price for coal is slightly higher than in 2003. Even a slight increase in price, when coupled with a substantial production increase, means more tax revenues to the State and better profit margins for the producers.

The continued high prices for energy minerals throughout 2004 prompted the higher forecast prices. . .

Oil production continued its yearly decrease (because depletion of large, known reservoirs and fields outstrips discovery and development of new reserves from smaller reservoirs and fields), but at a lesser rate than in past years. The good news for Wyoming oil is the $6.69 per barrel price increase in the first three quarters of 2004, and the $8.46 per barrel increase by the end of the year. The substantially increased price of oil more than offsets the decreased production, so again, Wyoming producers and the State of Wyoming benefit from the increased revenues. Unfortunately, the price of gasoline (which is refined from crude oil) has also increased, so Wyoming consumers do not directly benefit at the gas pump or in their pocketbooks from the increased tax base (valuation) and the increased revenues .

Coalbed methane (CBM or "coalbed natural gas") and trona production both declined slightly in the first three quarters of 2004 compared to 2003. CBM production from the Powder River Coal Field continues its slow decline, as new production wells cannot be completed fast enough to offset the decline or depletion at existing wells, and CBM production from the other Wyoming coal fields is not increasing enough to make up the difference. By the end of the year, CBM production will be about 4% less than in 2003. Trona production has also declined from 2003, but probably only by 1 or 2% by year's end. Excess capacity at the nation's soda ash plants, coupled with more competition internationally from synthetic soda ash may have contributed to the decline.

Production of yellowcake produced from Wyoming's two *in situ* uranium mines in 2004 was slightly less than in 2003 but the price of yellowcake rose substantially in the first three quarters of 2004. Production of other industrial minerals, including bentonite, gypsum, and construction aggregate, is expected to be about the same or slightly higher than the previous year; the domestic dimensional and decorative stone industry is currently in a slump due to competition from low-cost imports. The WSGS conducted investigations on gold, colored gemstones, and opal in the second and third quarters, and worked on proposals to continue the search for diamond deposits.

New forecasts for production and prices of Wyoming's minerals became available after the third quarter of 2004 (and revised slightly in January 2005) from the State of Wyoming's Consensus Revenue Estimating Group (CREG). The WSGS is an integral part of this group, and several staff geologists along with the State Geologist participate in the forecasts. CREG has carried the new estimates into 2009 and 2010; increased production estimates for the methane component of natural gas and for coal; decreased production estimates for oil, trona, and uranium; and has not changed estimates for the other components of natural gas, namely carbon dioxide and helium (**Table 1**; compare to Table 1 in *Wyoming Geo-notes No. 81*, November, 2004, p. 1). CREG also increased

the average prices for oil, methane, and coal; the price for trona was unchanged from CREG's 2003 forecast (**Table 2**; compare to Table 2 in *Wyoming Geo-notes No. 81*, November, 2004, p. 1). [Editor's note: CREG's forecast price for trona published in *Wyoming Geo-notes Nos. 79, 80, and 81* was incorrect, it should have been $35.50 per short ton instead of $37.50 per short ton.] Refer to the individual mineral update articles for a more complete discussion of these new forecasts.

The continued high prices for energy minerals (oil, natural gas, coal, and uranium) throughout 2004 prompted the higher forecast prices, even those for the out years (**Table 2**). Oil prices for 2004 were changed from the $22.50 per barrel forecast in 2003 to $36.00 per barrel forecast in 2004; natural gas forecasts went from $3.50 to $5.05 per thousand cubic feet (MCF), and coal price forecasts were raised from $6.00 to $6.88 per short ton.

The new oil production forecasts (**Table 1**) factored in the new tertiary production anticipated from proposed carbon dioxide floods and are slightly less optimistic than before, mainly based on the timing and completion of the proposed floods. Of significance here is the fact that Wyoming oil production is expected increase annually in a few years, reversing the annual decline that has occurred for many years. However, according to CREG, this will only be temporary since new reserves are not being discovered to offset depletion of existing fields.

By the end of 2004, natural gas production is expected to increase about 5.8% from 2003 and then increase by about 3% a year for the next six years. Since CBM production is declining slightly, the increased production is expected mostly from tight gas sand reservoirs in the Greater Green River Basin. Following the 5% increase in coal production from 2003 to 2004, CREG expects 2005 production to increase by 2% and then by 1% per year after that. Almost all the production increases will be from Campbell County in the Powder River Coal Field.

To handle the additional natural gas and coal that are going to be produced in Wyoming in the future, additional infrastructure will have to be added to get this production to the markets. The **Oil and Gas Update** describes expansion projects for increasing the capacity of two pipelines and the **Coal Update** describes the progress on constructing another rail line out of the PRB. Each year it is becoming more and more apparent that another rail line is needed; the question of increased competition reducing the costs of rail transportation now seems less important than the question of physically being able to move the produced coal out of the basin. The congestion on the existing rail lines appears to be affecting our production, and a close parallel can be drawn to natural gas pipeline capacity and natural gas production. However, it is a lot easier and less expensive to build a pipeline than a railroad. In addition, with all the new coal-fired electrical generating plants that have been proposed for the state, some serious upgrading of electrical transmission lines and facilities, as well as additional capacity for exporting electricity out of the state, should be on the drawing boards today, if not sooner.

Table 1. Wyoming mineral production (1987 through 2003) with forecasts to 2010[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	1571.0	174.0	1.20	373.2	17.2	1.4
2003	52.4	1636.9	196.0	1.20	376.6	17.8	1.2
2004	50.4	1742.8	196.0	1.20	393.7	17.1	1.2
2005	50.4	1808.8	196.0	1.20	401.6	17.0	1.5
2006	49.6	1876.8	196.0	1.20	405.6	17.1	1.9
2007	52.4	1939.8	196.0	1.20	409.6	17.0	2.5
2008	54.0	2008.8	196.0	1.20	413.7	17.0	2.5
2009	56.0	2064.8	196.0	1.20	417.9	17.0	2.5
2010	54.0	2130.8	196.0	1.20	422.1	17.0	2.5

[1]From CREG's Wyoming State Government Revenue Forecast, October 2004, revised January 2005; [2]Millions of barrels; [3]Wyoming Oil and Gas Conservation Commission, 1987 through 2003; [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 2003); [7]Millions of short tons (Wyoming Department of Revenue, 1987 through 2003; Wyoming State Inspector of Mines, 2003); [8]Millions of pounds of yellowcake (Wyoming Department of Revenue, 1987 through 1999; Wyoming State Inspector of Mines, 2000 through 2003).

Table 2. Average prices paid for Wyoming oil, methane, coal, and trona (1987 through 2003) with forecasts to 2010[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	26.63	4.41	6.85	37.40
2004	36.00	5.05	6.88	35.50
2005	33.00	4.75	6.95	35.50
2006	30.00	4.25	7.02	35.50
2007	30.00	4.25	7.09	35.50
2008	30.00	4.25	7.16	35.50
2009	30.00	4.25	7.23	35.50
2010	30.00	4.25	7.30	35.50

[1]From CREG's Wyoming State Government Revenue Forecast, October 2004, revised January 2005; [2]First purchase price in dollars per barrel (weighted average price for sweet, sour, heavy, stripper, and tertiary oil). Source: Energy Information Administration, 1987 through 2003; [3]Wellhead price in dollars per thousand cubic feet (MCF), includes coalbed methane. Source: American Gas Association, 1998 through 2003; Wyoming Office of State Lands and Investments, 1989 through 2003 (derived from State royalty payments); and Minerals Management Service, 1987 through 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 through 1990 and derived from Department of Revenue, 1991 through 2003; [5]Dollars per short ton of mined trona, not soda ash. Source Wyoming Department of Revenue, 1987 through 2003.

The **Coal Update** contains a summary of the five Wyoming PRB coal lease sales that occurred in 2004 and the revenues of about $1.3 billion that the State of Wyoming will be receiving in the next five years from these sales alone. The bonus bids were the highest ever on a per ton basis, and further demonstrates how valuable the state's coal reserves have become. The update also describes how some of the state's coal reserves can be better utilized to relieve the country's dependence on foreign energy sources. Certainly some of the revenues the State receives from the coal sales could go toward research into new technologies focused on new and improved uses for Wyoming's subbituminous coal.

The WSGS effort to produce and publish more geologic maps of Wyoming through a cooperative effort with the U.S. Geological Survey's STATEMAP program will continue for another year, as our latest proposal (STATEMAP 2005) was funded for the most part. The **Geologic Mapping, Paleontology, and Stratigraphy Update** details our latest proposal, for which the WSGS received funding of $94,804. The WSGS will match these funds to complete three of the proposed four subprojects. Geologic maps of the Midwest, Bill, and Sundance 1:100,000-scale quadrangles will be compiled (and/or mapped where necessary) along with digitizing four 1:24,000-scale quadrangles (Guernsey, Guernsey Reservoir, Miners Delight, and Pilot Hill), two 1:100,000-scale surficial geologic maps (Baggs and Medicine Bow quadrangles), and two 1:100,000-scale bedrock geologic maps (South Pass and Newcastle quadrangles). The WSGS is currently completing work on the STATEMAP 2004 project, which ends July 31, 2005.

This issue of *Wyoming Geo-notes* does not contain a Hazards Update, since James C. Case, Senior Staff Geologist–Surficial Processes and Hydrology (formerly Geologic Hazards), left the WSGS in October 2004 for the Wyoming Office of the Department of Homeland Security. In April 2005, the WSGS in cooperation with the above office, will publish a comprehensive report on Wyoming's natural hazards entitled *Wyoming Multi-Hazard Mitigation Plan*. The Wyoming Office of Homeland Security will distribute this report to State agencies and counties and will make the report accessible via their web site.

In place of the Hazards Update is a description of the **Annual Field Trip, 2004** that the WSGS re-instituted in September. The WSGS plans to offer a public field trip every year to geologic interesting areas of Wyoming in an effort to educate the public about the state's fascinating geology and mineral resources and allow the public to meet and interact with the WSGS staff. The fall trip was lead by the new State Geologist and Director of the WSGS, Ronald C. Surdam, who is a recognized expert and authority on the depositional environments and stratigraphy of the world-famous Green River Formation in southwestern Wyoming and adjoining Utah and Colorado. The field trip was very successful, informative, and entertaining. The 2005 WSGS field trip is a three-day trip to Yellowstone National Park in early June.

Oil and Gas Update

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Nearly all of the State of Wyoming's Consensus Revenue Estimating Group (CREG) projections were increased for oil and natural gas prices and natural gas production from those projections made last year. The new projections were in response to continued high prices for energy minerals.

Wyoming producers received higher prices in the first three quarters of 2004 for their oil and natural gas than they received during the corresponding period in 2003. Average oil prices for the first nine months of 2004 were up $6.69 per barrel over prices for the first nine months of 2003, while average natural gas prices were up $0.68 per thousand cubic feet (MCF). Natural gas production increased 5.7% for the first three quarters of 2004 while the decline in oil production was only 2.3%. Coalbed methane (CBM) production from the Powder River Basin (PRB) accounted for 246.9 billion cubic feet (BCF) or 17.2% of Wyoming's total natural gas production. Gas production from Jonah Field and from wells on the Pinedale anticline accounted for 299.2 BCF or 20.8% of Wyoming's total production.

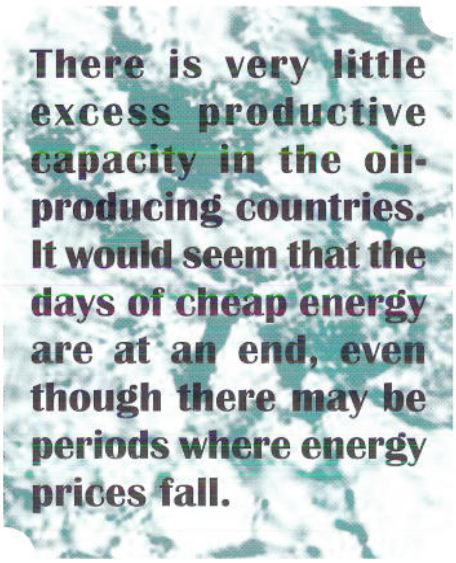
Three federal lease sales in April, June, and August brought in over $16.7 million and two state sales in April and June netted almost $5.8 million. Total revenue from federal and state lease sales in 2004 should exceed the total revenue for sales in 2000 and 2001, which were both outstanding years.

The number of applications for permit to drill in the first nine months of 2004 remained healthy with 6338 approvals. The WOGCC approved 46 seismic projects in the first nine months and the average daily rig count was 73. The rig count is the highest for three quarters in over 14 years; the average rig count for 2004 will be the highest since 1985.

CREG projections

CREG met in October 2004 to project prices and production for mineral commodities. These numbers are used to help project revenues to the State. Taxes on mineral production contribute a large part of the State's revenue stream. In the months that followed, natural gas and oil prices climbed

higher than CREG anticipated. Consequently, the projected price of natural gas for 2004 was increased from $4.90 to $5.05 per MCF at CREG's January 2005 meeting. The projected average price for crude oil was also increased from $33.00 to $36.00 per barrel for 2004 and from $30.00 to $33.00 per barrel for 2005. Preliminary figures suggest that average oil prices in 2004 will be closer to $35.00 and average natural gas prices will be closer to $5.17.



Oil production estimates were not changed from CREG's October meeting; however, in January 2005, natural gas production estimates were revised upward by 49 BCF per year over the entire forecast period of 2004 to 2010. CREG in its October meeting had already predicted average annual growth in natural gas production of 3% based on increased demand for this commodity, with more natural gas from coal beds and tight gas sands and less available natural gas from traditional sources. All the new price and production forecasts for oil and gas made by CREG are shown on **Tables 1** and **2**. These new forecasts are shown graphically in the ***Prices and production*** section below.

It now appears that expanding economies in China and India will compete with the U.S. and other oil-importing countries for oil supplies that are now very close to being in balance with demand. There is very little excess productive capacity in the oil-producing countries. It would seem that the days of cheap energy are at an end, even though there may be periods where energy prices fall.

Prices and production

Prices paid to Wyoming oil producers during the first three quarters of 2004 averaged $33.49 per barrel (**Table 3**), which is $6.69 higher than the average price in the first three quarters of 2003. The average monthly price of $45.35 in October 2004 was the highest average monthly price ever for Wyoming crude oil. The posted sweet and sour crude prices and first purchase price for Wyoming oil averaged by month increased steadily through the first three quarters of 2004 (**Figure 3**). The average monthly price for a barrel of Wyoming crude oil has been over $20 for the last 34 months (**Table 3** and **Figure 4**), and the average yearly price was over $20 per barrel for the fifth year in a row at the end of 2004 (**Figure 4**).

Oil production reported by the Wyoming Oil and Gas Conservation Commission (WOGCC) for the first three quarters of 2004 was 38.5 million barrels (**Table 4**). This production was only about 900,000 barrels less than production in the first three quarters of 2003 but still amounted to a 2.3% decline. The decline rate is lower than normal because prices have been very high this year and will average about $35 per barrel by year-end. The high prices prevented abandoning many stripper wells. Two major enhanced oil recovery (EOR) projects were started this year by Anadarko Petroleum. The EOR projects involve injecting liquid carbon dioxide into nearly depleted oil reservoirs at Patrick Draw and Salt Creek fields and should help Wyoming's declining oil production to level out or increase slightly over the next several years (**Figure 5**).

Spot prices for natural gas at Opal, Wyoming averaged $5.04 per MCF during the first nine months of 2004. This is $0.68 per MCF higher than the average price for the corresponding period in 2003 (**Table 5** and **Figure 6**). Spot prices for natural gas have been over $4.00 per MCF for 20 straight months (**Table 5**) and the average spot price of Wyoming natural gas in 2004 reached an all-time high (**Figure 7**). Natural gas prices before 1980 seldom exceeded $2.00 per MCF.

Natural gas production in Wyoming for the first nine months of 2004 was about 1.4 trillion cubic feet (TCF) according to production figures from the WOGCC. This production is up 79.1 BCF or 5.8% from the first three quarters of 2003 (**Table 6**). CBM production from the PRB accounted for 246.9 BCF or 17.2% of the total for that period. Level gas produc-

Table 3. Monthly average price of a barrel of oil produced in Wyoming (2000 through December 2004).

	2000		2001		2002		2003		2004	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	$24.01	$24.01	$24.62	$24.62	$15.70	$15.70	$28.02	$28.02	$28.88	$28.88
February	$26.48	$25.25	$24.82	$24.72	$16.63	$16.17	$31.00	$29.51	$29.40	$29.14
March	$27.24	$25.91	$22.71	$24.05	$20.64	$17.66	$28.92	$29.31	$31.36	$29.88
April	$22.92	$25.16	$22.85	$23.75	$22.63	$18.90	$24.50	$28.11	$31.22	$30.22
May	$26.06	$25.34	$23.68	$23.74	$22.86	$19.69	$24.51	$27.39	$34.31	$31.03
June	$28.31	$25.84	$22.99	$23.61	$21.71	$20.03	$26.55	$27.25	$32.68	$31.31
July	$27.12	$26.02	$22.55	$23.46	$23.29	$20.49	$26.37	$27.12	$35.25	$31.87
August	$28.18	$26.29	$23.67	$23.49	$24.27	$20.97	$27.20	$27.13	$39.16	$32.78
September	$30.22	$26.73	$22.02	$23.32	$25.47	$21.47	$24.16	$26.80	$39.12	$33.49
October	$28.75	$26.93	$17.71	$22.76	$24.27	$21.75	$25.71	$26.69	$45.35	$34.67
November	$29.63	$27.17	$16.44	$22.19	$22.66	$21.83	$25.63	$26.60	$39.90	$35.15
December	$23.60	$26.88	$14.86	$21.58	$24.85	$22.08	$26.98	$26.63	**$34.50**	**$35.09**
Average yearly price		**$26.88**		**$21.58**		**$22.08**		**$26.63**		**$35.09**

All averages are derived from published monthly reports by the Energy Information Administration, except that averages in bold print in 2004 are estimated from various unpublished bulletins listing posted prices. *Wyoming State Geological Survey, Oil and Gas Section, April 2005.*

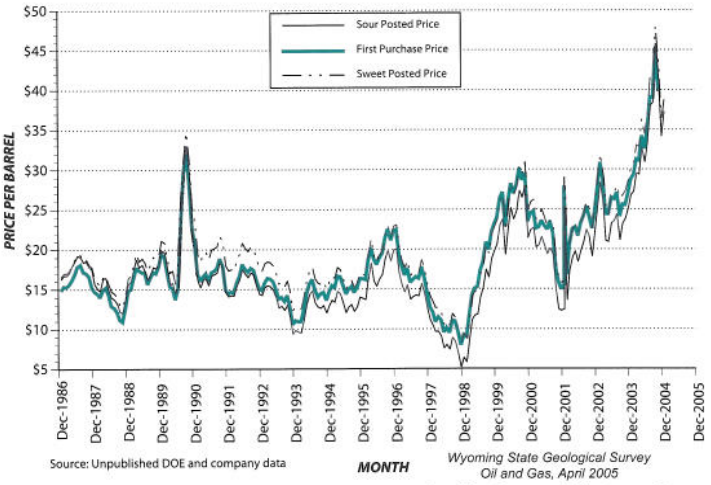


Figure 3. Wyoming posted sweet and sour crude oil prices and first purchase prices, averaged by month (January 1987 through December 2004).

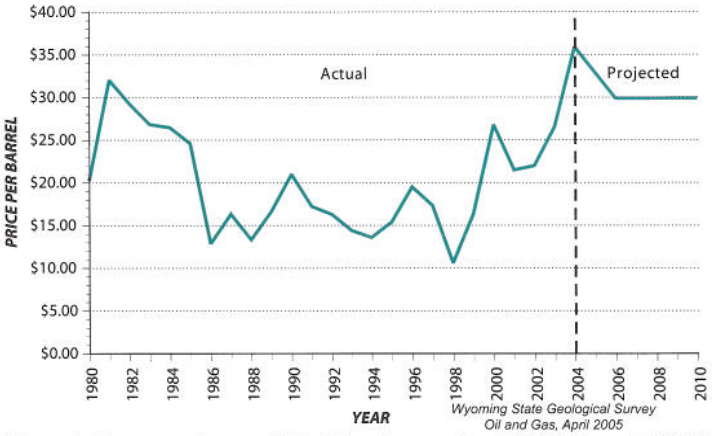


Figure 4. Average prices paid for Wyoming crude oil (1980 through 2004) with forecasts to 2010.

tion from Jonah Field compared to last year and increased production from wells on the Pinedale anticline accounted for 299.2 BCF, or 20.8% of Wyoming's total production for the first three quarters. Production from these unconventional gas reservoirs in the Green River Basin will be responsible for nearly all the yearly increases in the state's natural gas production, while CBM's role in these increases is less than we predicted earlier (compare **Figure 8** with Figure 7 in *Wyoming Geo-notes No. 81*, November 2004, p. 9).

Reports and projects

The U.S. Department of Energy, 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 beginning of 2004, Wyoming ranked second in dry natural gas reserves, third in natural gas liquids, and sixth in crude oil reserves (**Table 7**). Wyoming had the third largest increase of any state in proved reserves of dry natural gas with over 1.2 TCF of gas added (**Table 8**). Only Colorado and Texas added more proved reserves of dry natural gas than Wyoming. Most of Wyoming's increase came

Table 4. Monthly oil production from Wyoming in barrels (2000 through November 2004).

	2000		2001		2002		2003		2004	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	5,187,557	5,187,557	5,003,766	5,003,766	4,711,532	4,711,532	4,617,857	4,617,857	4,323,372	4,323,372
February	4,873,042	10,060,599	4,495,136	9,498,902	4,238,372	8,949,904	4,130,199	8,748,056	4,046,413	8,369,785
March	5,213,721	15,274,320	4,972,168	14,471,070	4,629,468	13,579,372	4,473,585	13,221,641	4,367,920	12,737,705
April	5,014,266	20,288,586	4,804,531	19,275,601	4,565,445	18,144,817	4,345,365	17,567,006	4,188,323	16,926,028
May	5,205,848	25,494,434	4,933,201	24,208,802	4,687,127	22,831,944	4,469,085	22,036,091	4,309,886	21,235,914
June	5,005,008	30,499,442	4,678,672	28,887,474	4,495,524	27,327,468	4,246,526	26,282,617	4,239,537	25,475,451
July	5,083,393	35,582,835	4,854,173	33,741,647	4,595,080	31,922,548	4,413,901	30,696,518	4,348,250	29,823,701
August	5,108,431	40,691,266	4,768,811	38,510,458	4,626,308	36,548,856	4,368,236	35,064,754	4,413,561	34,237,262
September	4,990,825	45,682,091	4,726,876	43,237,334	4,492,324	41,041,180	4,334,149	39,398,903	4,279,574	38,516,836
October	5,165,311	50,847,402	4,834,294	48,071,628	4,623,348	45,664,528	4,436,608	43,835,511	4,415,251	42,932,087
November	4,884,659	55,732,061	4,655,985	52,727,613	4,456,006	50,120,534	4,200,472	48,035,983	4,228,914	47,161,001
December	4,987,669	60,719,730	4,763,863	57,491,476	4,596,150	54,716,684	4,373,237	52,409,220		
Total Barrels Reported [1]	**60,719,730**		**57,491,476**		**54,716,684**		**52,409,220**			

[1]Monthly production reports are from Wyoming Oil and Gas Conservation Commission. *Wyoming State Geological Survey, Oil and Gas Section, April 2005.*

Table 5. Monthly average spot sale price for a thousand cubic feet (MCF) of natural gas at Opal, Wyoming (2000 through December 2004).

	2000		2001		2002		2003		2004	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	$2.20	$2.20	$8.75	$8.75	$2.35	$2.35	$3.20	$3.20	$5.57	$5.57
February	$2.40	$2.30	$6.60	$7.68	$1.75	$2.05	$4.73	$3.97	$4.77	$5.17
March	$2.35	$2.32	$4.90	$6.75	$2.00	$2.03	$4.34	$4.09	$4.78	$5.04
April	$2.70	$2.41	$4.55	$6.20	$2.85	$2.24	$3.76	$4.01	$5.04	$5.04
May	$2.70	$2.47	$4.10	$5.78	$2.30	$2.25	$4.81	$4.17	$5.44	$5.12
June	$3.65	$2.67	$2.60	$5.25	$1.60	$2.14	$4.96	$4.30	$5.14	$5.12
July	$3.90	$2.84	$2.05	$4.79	$1.25	$2.01	$4.52	$4.33	$5.32	$5.15
August	$3.10	$2.88	$2.25	$4.48	$1.60	$1.96	$4.65	$4.37	$4.89	$5.12
September	$3.40	$2.93	$2.10	$4.21	$1.20	$1.88	$4.29	$4.36	$4.42	$5.04
October	$4.30	$3.07	$1.25	$3.92	$2.04	$1.89	$4.23	$4.35	$5.31	$5.07
November	$4.35	$3.19	$2.60	$3.80	$3.04	$2.00	$4.18	$4.33	$5.35	$5.09
December	$6.00	$3.42	$2.15	$3.66	$3.08	$2.09	$5.27	$4.41	$5.95	$5.17
Average Yearly Price	**$3.42**		**$3.66**		**$2.09**		**$4.41**		**$5.17**	

Source: American Gas Association's monthly reports. Starting in October, 2002, averages calculated from weekly prices posted on Enerfax website. *Wyoming State Geological Survey, Oil and Gas Section, April 2005.*

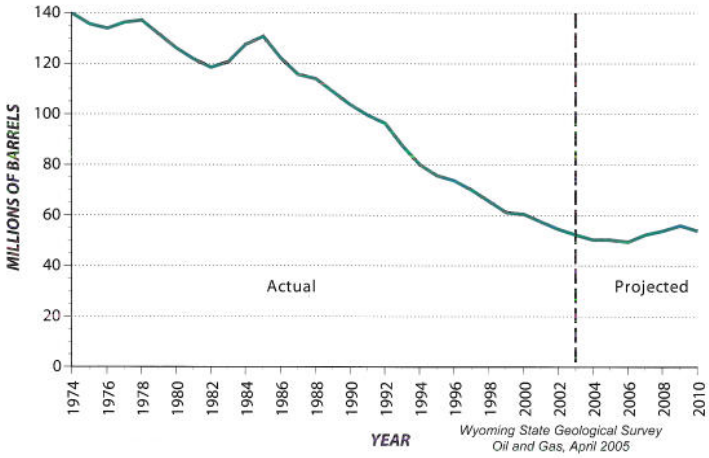


Figure 5. Annual crude oil production from Wyoming (1980 through 2003) with forecasts to 2010.

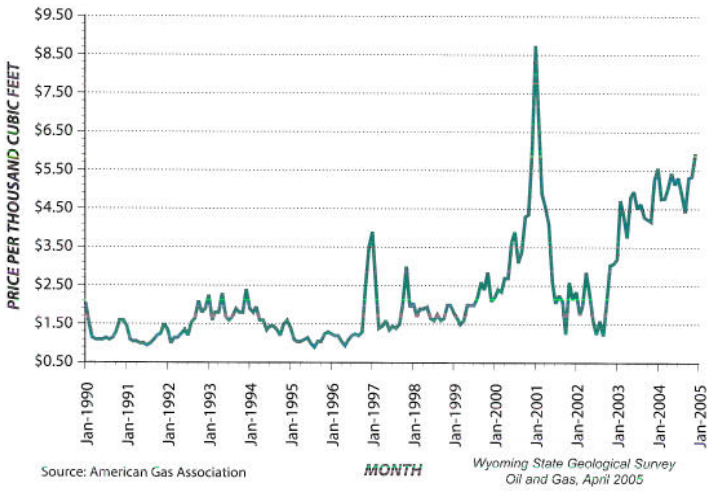


Figure 6. Spot sales prices for methane at Opal, Wyoming, averaged by month (January 1990 through December 2004).

from development drilling at Jonah Field, on the Pinedale anticline, and from CBM development in the PRB. Proved reserves of CBM are now almost 2.8 TCF and represent almost 13% of Wyoming's proved reserves of dry natural gas. Over the last three years, Wyoming has added almost 5.6 TCF of proved reserves, more dry natural gas reserves than any other state. During that period, Wyoming's natural gas production was 5.2 TCF, meaning Wyoming gas producers are finding more reserves than they are producing.

Wyoming remained in sixth place in proved crude oil reserves (**Table 7**), even though reserves were revised downward by 7 million barrels (**Table 8**). The EIA also revised Wyoming's proved reserves of natural gas liquids downward by 5 million barrels (**Table 8**), but Wyoming remained in third place among the states (**Table 7**).

The U.S. Minerals Management Service (MMS) announced the distribution of $1.32 billion in federal revenue shares for calendar year 2004. This total compares to $1.1 billion in

Table 6. Monthly natural gas production from Wyoming in thousands of cubic feet (MCF) (2000 through November 2004).

	2000		2001		2002		2003		2004	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	122,320,888	122,078,095	135,998,574	135,998,574	143,510,891	143,510,891	161,162,853	161,162,853	160,797,044	160,797,044
February	112,851,735	235,172,623	123,506,503	259,505,077	132,981,761	276,492,652	145,026,305	306,189,158	151,344,848	312,141,892
March	121,287,580	356,460,203	139,126,687	398,631,764	143,707,799	420,200,451	159,734,697	465,923,855	162,622,561	474,764,453
April	118,886,204	475,346,407	132,684,058	531,315,822	141,016,463	561,216,914	151,047,796	616,971,651	157,214,903	631,979,356
May	118,631,057	593,977,464	138,214,926	669,530,748	146,950,768	708,167,682	143,493,146	760,464,797	162,295,453	794,274,809
June	117,033,775	711,011,239	128,145,994	797,676,742	141,386,350	849,554,032	146,507,531	906,972,328	156,606,478	950,881,287
July	120,838,202	831,849,441	131,752,355	929,429,097	145,796,954	995,350,986	149,789,416	1,056,761,744	162,219,320	1,113,100,607
August	122,698,001	954,547,442	132,847,188	1,062,276,285	139,407,056	1,134,758,042	149,206,628	1,205,968,372	164,161,194	1,277,261,801
September	120,166,494	1,074,713,936	131,334,584	1,193,610,869	142,448,905	1,277,206,947	150,567,184	1,356,535,556	158,402,100	1,435,663,901
October	127,682,448	1,202,396,384	137,507,181	1,331,118,050	151,247,991	1,428,454,938	159,308,221	1,515,843,777	166,277,227	1,601,941,128
November	123,108,333	1,325,504,717	136,878,261	1,467,996,311	155,751,286	1,584,206,224	155,178,164	1,671,021,941	162,684,131	1,764,625,259
December	131,474,722	1,456,979,439	144,790,631	1,612,786,942	162,039,833	1,746,246,057	163,090,284	1,834,112,225		
Total MCF Reported [1]		**1,456,979,439**		**1,612,786,942**		**1,746,246,057**		**1,834,112,225**		

[1] Monthly production reports are from Wyoming Oil and Gas Conservation Commission. *Wyoming State Geological Survey, Oil and Gas Section, April 2005.*

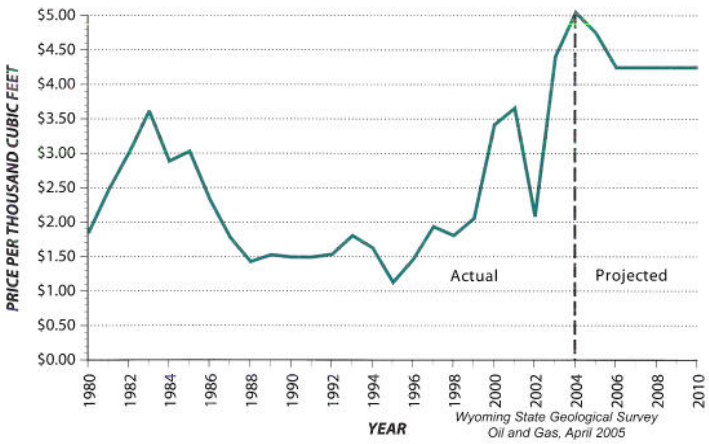


Figure 7. Average prices paid for Wyoming natural gas (1980 through 2004) with forecasts to 2010.

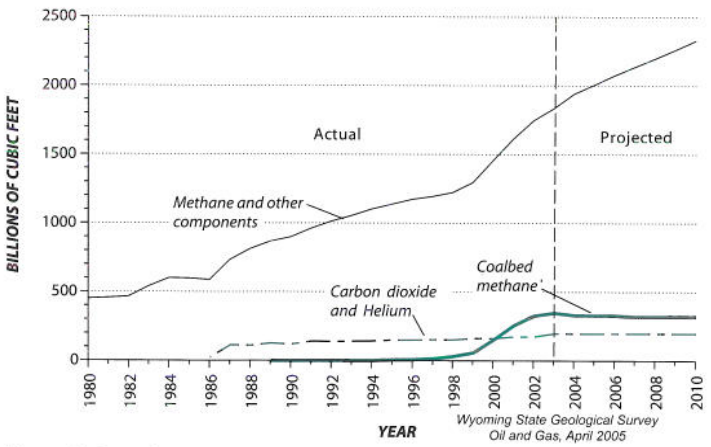


Figure 8. Annual natural gas production from Wyoming (1980 through 2003) with forecasts to 2010.

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 2004.

State	Crude Oil	State	Dry Natural Gas	State	Natural Gas Liquids
Texas	4.583	Texas	45.730	Texas	2.517
Alaska	4.446	**Wyoming**	**21.744**	New Mexico	0.875
California	3.452	New Mexico	17.020	**Wyoming**	**0.775**
New Mexico	0.677	Colorado	15.436	Oklahoma	0.688
Oklahoma	0.588	Oklahoma	15.401	Colorado	0.395
Wyoming	**0.517**	Louisiana	9.325	Alaska	0.387
Louisiana	0.452	Alaska	8.285	Louisiana	0.295
North Dakota	0.353	Kansas	4.819	Kansas	0.248
Montana	0.315	Alabama	4.301	Utah	0.123
Kansas	0.243	Utah	3.516	California	0.101

Source: Energy Information Administration, 2004. *Wyoming State Geological Survey, Oil and Gas Section, April 2005.*

calendar year 2003. Wyoming again led the way with $604.4 million, or 45.8% of the total distribution. New Mexico was a distant second with $382.8 million. Wyoming received $503.0 million in calendar year 2003.

Contracts for about 2100 barrels per day of royalty-in-kind crude oil were awarded to seven companies this month as part of a joint sale conducted by the MMS and the State of Wyoming. The sale included both federal and state crude oil. The six-month contracts call for deliveries to begin April 1, 2005. The February sale was the 14th in a series of joint sales dating back to 1998 when Wyoming and MMS first entered into the Wyoming Oil Pilot Program. MMS and the State took their royalties-in-kind in the form of oil, rather than in cash payments, and competitively sold the oil in the marketplace. The amount of oil sold in this program only represents a very small portion of the oil produced on federal and state land.

The Federal Energy Regulatory Commission approved an expansion of Cheyenne Plains Gas Pipeline to 730 million cubic feet (MMCF) per day. The 380-mile interstate natural gas pipeline began transporting Wyoming natural gas supplies from the Cheyenne Hub (just south of the Wyoming state line in northern Colorado) to southwestern Kansas at the end of 2004.

TEPPCO Partners L.P. plan a $122 million Phase IV expansion of the Jonah gas gathering system in southwestern Wyoming that will expand the system capacity to approximately 1.5 BCF of gas per day. The expansion should be operational by December 2005. The expansion will include about 45 miles of pipeline that will loop Jonah's gathering system, as well as add compression at three stations. The production for Jonah and Pinedale is over 1.1 BCF per day and is approaching the limits of the existing system.

In a related item, the U.S. Bureau of Land Management (BLM) in Pinedale has released its Draft Environmental Impact Statement (DEIS) for the Jonah Infill Drilling Project Proposal. The operators in Jonah Field proposed to expand development of gas and condensate from the Lance and other formations at depths of about 11,000 feet by drilling as many as 3100 additional wells on up to 16,200 acres of new surface disturbance during the drilling phase. Well spacing could be as low as 5 acres in some parts of the field. The BLM's "preferred alternative" would reduce the disturbance by limiting the number of well pads and would require more directional drilling than the operator's proposal to develop the remaining estimated resources of almost 8 TCF of natural gas and 75 million barrels of condensate. The BLM's analysis is flawed in that it assumes that the "preferred alternative" will recover almost the same amount of gas as the "proposed action" would recover. Requiring directional drilling in this field will add expense and will increase operational problems, which makes the recovery of a substantial amount of gas uneconomical. More gas and condensate will be left in the ground with directional drilling requirements, the State and Sublette County will receive less revenue, and the energy provided by clean-burning natural gas needed by this country will have to come from other countries or from other fossil fuels.

The BLM's Rawlins Field Office released the DEIS for its revised Resource Management Plan. The "reasonably foreseeable development" for the 20-year planning period includes a projected 8822 wells to be drilled; 2675 miles of new oil and gas roads; 57,545 acres of short-term disturbance; 1184 wells abandoned; 1066 well sites reclaimed; 500 miles of roads reclaimed; and 15,472 acres of long-term disturbance. The DEIS classifies 853,690 acres open to leasing with standard lease form stipulations; 3,279,670 acres open to leasing subject to minor lease constraints such as seasonal restrictions; 377,590 acres subject to major lease constraints such as no surface occupancy; and 76,950 acres closed to leasing.

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 2003.

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
2003	0.517	21.744	0.775

[1]Estimated from Energy Information Administration figures. Source: Energy Information Administration, 2004. *Wyoming State Geological Survey, Oil and Gas Section, April 2005.*

Western Gas Resources completed the acquisition of natural gas gathering and processing assets in the eastern Greater Green River Basin from Duke Energy Field Services, Overland Trail Transmission, and Duke Energy Field Services Marketing for a total of $27.9 million. The acquisition includes the Patrick Draw processing plant with 150 MMCF of gas per day of capacity and about 140 miles of related gathering systems.

The increased number of approved APDs in Fremont County was due to accelerated drilling for natural gas in the Wind River Basin.

Lease sales

There were three federal oil and gas lease sales in the second and third quarters of 2004. In total, they generated nearly $16.8 million, resulting in 283 parcels covering 227,165 acres being leased (**Table 9**). Half the proceeds from these sales are returned to the State of Wyoming. Leasing activity at the April BLM sale was concentrated in the PRB (**Figure 9**). The high per-acre bid of $1250 was made by Hanson & Strahn for a 241.3-acre lease that covers parts of section 2, T42N, R77W (**location A, Figure 9**). The lease is in the Fort Union Formation CBM play in an area that is being developed by Williams Production. The second high per-acre bid of $1100 was made by CH4 Energy for a 39.34-acre tract that covers part of sec 17, T44N, R74W (**location B, Figure 9**). The lease is in an area of CBM development about 12 miles northwest of Wright. The sale generated about $2.4 million and the average per-acre bid was $55.91 (**Table 9**). There were 17 parcels at this sale that received a bid of $50 or more per acre.

A tract on the Pinedale anticline drew the high bid at the BLM's June sale. Questar Exploration & Production paid $1100 an acre for a 1424.12-acre lease that covers parts of

Table 9. Federal and state competitive oil and gas lease sales in Wyoming (1999 through August 2004).

Federal Sales (U.S. Bureau of Land Management)								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	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								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	April	$1,815,526	299	196	123,119	89,194	$20.35	$890.00
June	$8,358,363	179	155	233,599	207,978	$40.19	$32,000.00	June	$1,002,039	300	190	108,310	69,858	$14.34	$400.00
August	$3,294,339	206	197	215,631	208,777	$15.78	$290.00	October	$2,369,527	300	216	109,140	77,261	$30.67	$475.00
October	$4,395,288	214	175	195,827	142,525	$30.84	$580.00	December	$956,113	291	129	115,502	51,674	$18.50	$500.00
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**	**Total**	**$6,143,205**	**1,190**	**731**	**456,071**	**287,987**	**$21.33**	**$890.00**
			2000								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	April	$1,475,661	299	191	120,319	71,933	$19.54	$525.00
June	$6,387,887	230	184	260,294	190,306	$33.57	$410.00	June	$2,119,198	300	197	127,798	79,743	$26.58	$775.00
August	$5,213,595	240	222	174,040	154,920	$33.65	$475.00	October	$1,660,315	300	216	117,598	81,603	$20.35	$268.00
October	$5,028,610	147	129	149,934	124,724	$40.32	$510.00	December	$1,240,442	300	192	109,375	62,636	$19.80	$210.00
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**	**$35.10**	**$725.00**	**Total**	**$6,495,616**	**1,199**	**796**	**475,090**	**295,915**	**$21.95**	**$775.00**
			2001								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	April	$2,250,353	300	212	112,379	82,834	$27.16	$450.00
August	$7,626,362	204	190	260,409	245,116	$31.11	$525.00	June	$1,754,320	300	192	111,507	66,829	$26.25	$650.00
October	$998,308	119	105	127,396	107,880	$9.25	$160.00	October	$679,343	300	129	112,255	53,396	$12.72	$120.00
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**	**Total**	**$4,684,016**	**900**	**533**	**336,141**	**203,059**	**$23.07**	**$650.00**
			2002								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	April	$465,104	200	90	74,321	35,084	$13.26	$105.00
August	$858,686	124	89	111,462	88,719	$9.68	$205.00	June	$517,143	200	124	74,608	46,481	$11.04	$525.00
October	$578,597	117	86	122,962	72,039	$8.03	$46.00	October	$1,222,823	198	133	70,800	47,436	$25.77	$480.00
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**	**Total**	**$2,205,070**	**598**	**347**	**219,729**	**129,001**	**$17.09**	**$525.00**
			2003								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	April	$812,916	200	92	79,290	30,152	$26.96	$350.00
August	$3,357,650	177	104	233,189	121,515	$27.63	$675.00	June	$583,950	200	121	76,433	43,966	$13.28	$575.00
October	$4,173,493	94	82	70,892	64,072	$65.14	$990.00	October	$1,978,075	199	113	75,614	37,205	$53.16	$2025.00
December	$5,698,724	149	136	117,076	100,188	$56.88	$1110.00								
Total	**$16,585,469**	**618**	**474**	**545,926**	**379,002**	**$43.76**	**$1110.00**	**Total**	**$3,374,941**	**599**	**326**	**231,337**	**111,323**	**$30.32**	**$2025.00**
			2004								2004				
February	$7,063,343	96	85	84,593	75,406	$93.67	$2012.00								
April	$2,449,529	66	63	47,517	43,813	$55.91	$1250.00	April	$2,831,939	200	149	71,014	56,146	$50.43	$1510.00
June	$10,302,576	167	157	144,806	132,076	$78.00	$1100.00	June	$2,953,359	200	171	81,020	71,015	$41.59	$510.00
August	$4,009,097	74	63	66,093	51,276	$78.19	$870.00								

Sources: Wyoming Office of State Lands and Investments, Petroleum Information/Dwights LLC - Rocky Mountain Region Report, and U.S. Bureau of Land Management.
Wyoming State Geological Survey, Oil and Gas Section, April 2005.

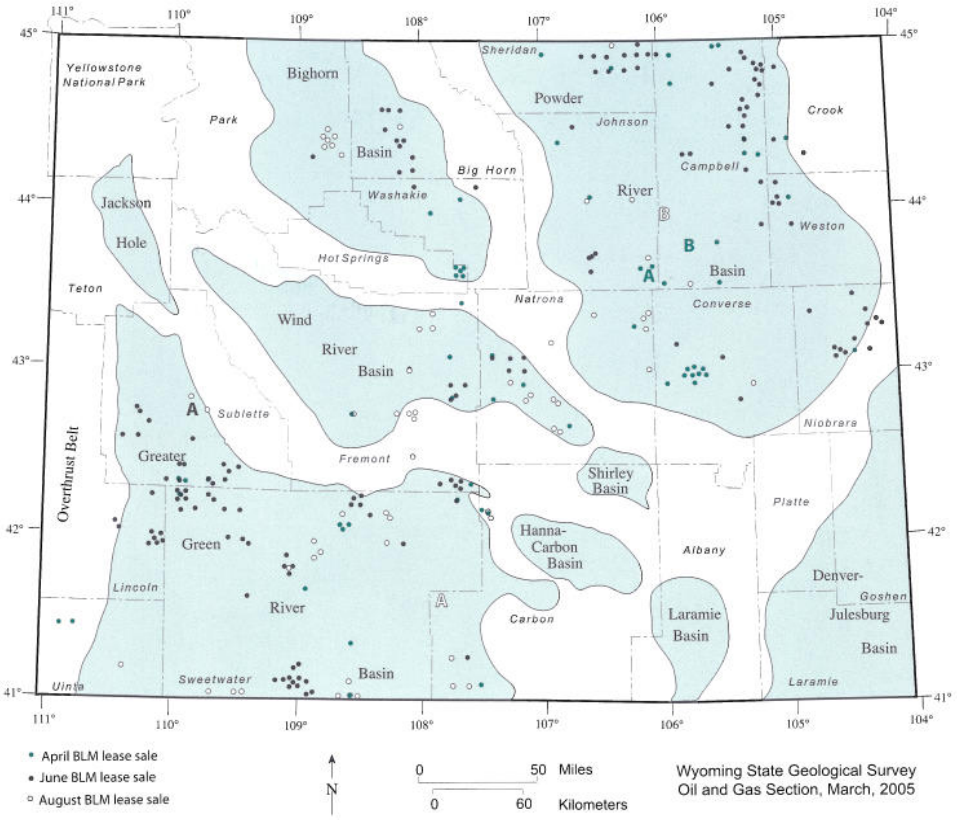


Figure 9. Locations of federal oil and gas tracts leased by the U. S. Bureau of Land Management at its April, June, and August 2004 sales. Locations are approximate and may represent more than one tract.

sections 30 and 31, T32N, R109W (**location A, Figure 9**). Leasing activity at this sale was concentrated in the PRB and in southwestern Wyoming (**Figure 9**). The sale generated about $10.3 million and the average high per-acre bid was $78.00 (**Table 9**). There were 59 parcels at this sale that received a bid of $50 or more per acre and 34 of those bids were $100 or more per acre.

Leasing activity at the August BLM sale was concentrated in southwestern Wyoming and in the Wind River Basin (**Figure 9**). The high per-acre bid of $870 was made by T.S. Dudley Land Company for a 160-acre tract that covers the SE section 32, T19N, R92W, and is in the area of Echo Springs Field (**location A, Figure 9**). The second high per-acre bid of $760 was made by Johnson, Grassel, and Gorham for a 196.7-acre tract that covers parts of sections 3 and 24, T46N, R76W in an area of Fort Union CBM development (**location B, Figure 9**). The day before the sale, 44 parcels under the jurisdiction of the BLM's Newcastle Field Office were withdrawn from the sale because of a protest filed by the Denver-based Center for Native Ecosystems and Biodiversity in conjunction with the Biodiversity Conservation Alliance. Those parcels will be offered in a later sale after the Newcastle office consults with the U.S. Fish and Wildlife Service about the acreage located in Crook, Weston, and Niobrara counties. The sale still managed to generate over $4.0 million with an average high bid of $78.19 (**Table 9**).

There were two State of Wyoming lease sales in the second and third quarters of 2004, netting about $5.9 million. Some 320 parcels covering 127,161 acres were leased (**Table 9**). The April sale held by the Office of State Lands and Investments (State Lands) drew high bids totaling over $2.8 million with an average high bid of $50.43 per acre (**Table 9**). The high per-acre bid of $1510 was made by Strata Oil and Gas for a 160-acre tract that covers NW section 36, T43N, R76W (**location A, Figure 10**) and is near CBM production from the Big George coal zone. The second high per-acre bid of $1320 was made by T.S. Dudley Land Company for a 160-acre lease that covers NW section 13, T49N, R79W in an area of Fort Union CBM development (**location B, Figure 10**). Leasing activity at this sale was concentrated in the PRB (**Figure 10**) and a total of 35 tracts received bids of $50 or more per acre.

The average daily rig count for the first three quarters of 2004 was 73. . .the highest for the first three quarters in over 14 years.

Leasing activity at the June State Lands sale was concentrated in the PRB and in southwestern Wyoming (**Figure 10**). The high per-acre bid of $510 was made by Yates Petroleum for a 640-acre parcel in the Wind River Basin that includes all of section 16, T36N, R92W (**location A, Figure 10**). The lease is about a mile and a half west of a wildcat permitted by Yates to test the Lance Formation.

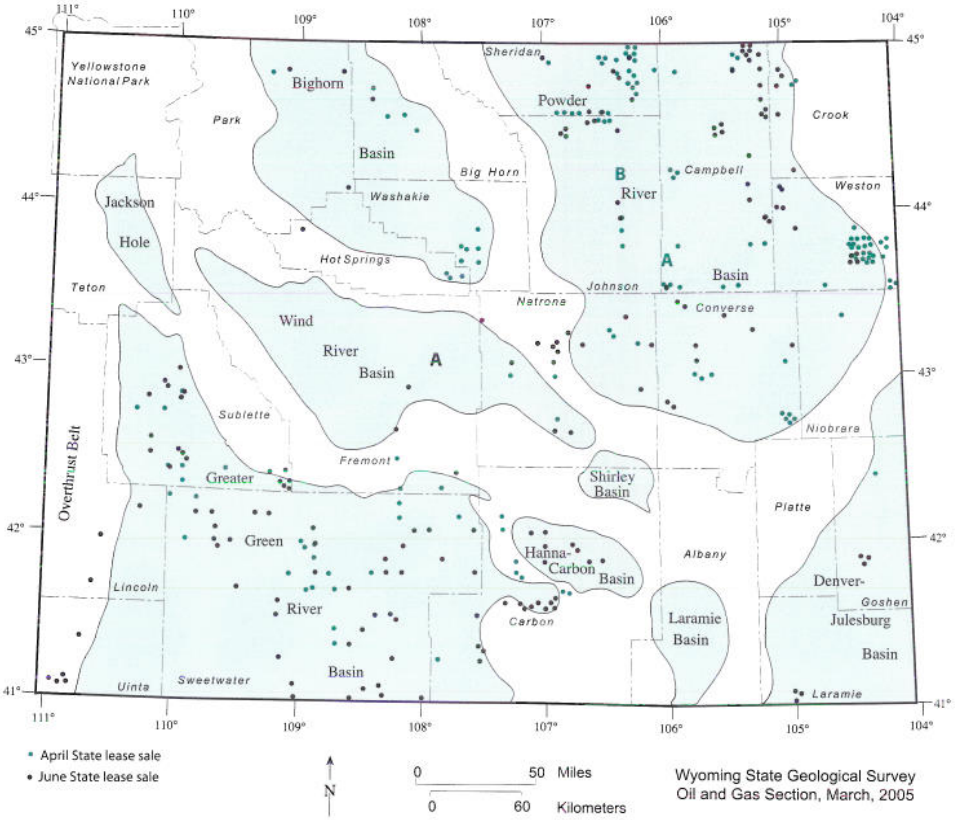


Figure 10. Locations of state oil and gas tracts leased by the Office of State Lands and Investments at its April and June 2004 sales. Locations are approximate and may represent more than one tract.

Table 10. Number of Applications for Permit to Drill (APDs) approved by the Wyoming Oil and Gas Conservation Commission (1998 through September 2004).

County	1998 APDs	1999 APDs	2000 APDs	2001 APDs	2002 APDs	2003 APDs	2004 APDs
Albany	0	0	0	1	1	1	0
Big Horn	13	6	11	23	8	5	2
Campbell	1586	4461	5580	6204	2793	2747	2587
Carbon	96	127	174	261	198	278	161
Converse	6	19	70	25	43	86	62
Crook	29	30	47	20	13	52	3
Fremont	76	67	136	149	62	133	187
Goshen	0	0	0	0	1	0	0
Hot Springs	1	8	6	2	9	8	11
Johnson	49	304	769	805	799	1155	1333
Laramie	2	0	2	3	3	1	3
Lincoln	105	51	70	87	51	72	82
Natrona	36	51	53	45	49	146	130
Niobrara	8	5	18	15	10	14	7
Park	11	12	18	45	23	56	41
Platte	0	0	0	0	0	0	0
Sheridan	35	416	891	1811	1531	1421	1087
Sublette	230	189	338	435	428	486	325
Sweetwater	181	124	335	534	379	591	283
Teton	0	0	0	0	0	0	0
Uinta	26	26	53	35	16	17	17
Washakie	9	0	7	10	1	0	7
Weston	6	4	20	7	2	14	10
Totals	**2505**	**5900**	**8598**	**10,517**	**6420**	**7283**	**6338**

Source: All data are from the Wyoming Oil and Gas Conservation Commission. *Wyoming State Geological Survey, Oil and Gas Section, April 2005.*

There were 24 parcels at this sale that received bids of $50 or more per acre; the sale generated almost $3.0 million in high bids (**Table 9**).

Permitting and drilling

The WOGCC approved 6338 Applications for Permit to Drill (APDs) in the first three quarters of 2004 (**Table 10**). Campbell County again led with 40.8% of the total APDs; Sheridan and Johnson counties combined for another 38.2% of the total APDs that were approved. Nearly all of the approved APDs in these three counties were for CBM tests and nearly all of the 1040-APD increase over the first three quarters of 2003 can be attributed to an increase in CBM permits in these counties. Approved APDs in Sweetwater, Sublette, and Carbon counties were fairly high because companies are emphasizing the development and exploration for natural gas reserves in southwestern Wyoming. The increased number of approved APDs in Fremont County was due to accelerated drilling for natural gas in the Wind River Basin.

The WOGCC permitted 46 seismic projects in the first three quarters of 2004. The number of permitted conventional miles of seismic lines has already exceeded the total for all of

Table 11. Number of seismic projects and miles permitted by the Wyoming Oil and Gas Conservation Commission (2001 through September 2004).

	2001			2002			2003			2004		
County	Permits	Conventional Miles	3-D Square Miles	Permits	Conventional Miles	3-D Square Miles	Permits	Conventional Miles	3-D Square Miles	Permits	Conventional Miles	3-D Square Miles
Albany	0	0	0	1	6	0	0	0	0	0	0	0
Big Horn	1	0	4	0	0	0	0	0	0	0	0	0
Campbell	5	38	3	10	49	3	4	8	3	3	9	1
Carbon	1	500	0	4	419	3	1	0	55	0	0	0
Converse	0	0	0	2	6	47	1	0	75	0	0	0
Crook	4	32	0	1	0	2	3	46	0	4	30	0
Fremont	2	70	15	1	160	0	4	12	717	5	3	139
Goshen	0	0	0	0	0	0	0	0	0	0	0	0
Hot Springs	0	0	0	0	0	0	0	0	0	1	8	0
Johnson	2	4	4	1	16	0	1	25	0	1	7	0
Laramie	0	0	0	1	0	18	0	0	0	0	0	0
Lincoln	1	0	25	0	0	0	0	0	0	2	12	73
Natrona	2	19	63	4	11	72	0	0	0	7	20	240
Niobrara	1	0	16	3	3	52	2	0	42	1	6	0
Park	4	21	20	0	0	0	1	0	6	2	0	63
Platte	0	0	0	0	0	0	0	0	0	0	0	0
Sheridan	2	0	81	0	0	0	0	0	0	1	37	0
Sublette	10	261	374	1	464	0	2	0	238	6	65	68
Sweetwater	11	129	802	7	348	485	5	1	246	11	32	524
Teton	0	0	0	0	0	0	0	0	0	0	0	0
Uinta	1	259	0	2	196	0	1	0	47	0	0	0
Washakie	0	0	0	1	21	0	1	4	0	1	0	14
Weston	0	0	0	0	0	0	0	0	0	1	0	4
Totals	**47**	**1333**	**1407**	**39**	**1699**	**682**	**26**	**96**	**1429**	**46**	**229**	**1126**

Source: All data are from the Wyoming Oil and Gas Conservation Commission. *Wyoming State Geological Survey, Oil and Gas Section, April 2005.*

2003, and the amount of 3-D seismic is about equal to that for the same time period in 2003 (**Table 11**). Geophysical activity is a good indicator of future exploration and production drilling.

The average daily rig count for the first three quarters of 2004 was 73. This average is the highest for the first three quarters in over 14 years (**Figure 11**). 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**).

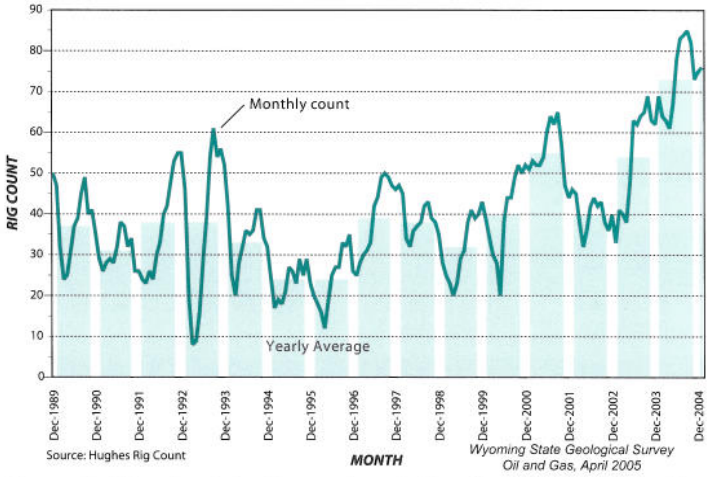


Figure 11. Wyoming daily rig count, exclusive of coalbed methane rigs, averaged by month and year (December 1989 through January 2005).

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 successful activities exclusive of coalbed methane (see the **Coalbed Methane Update** for development in that industry) during the second and third quarters of 2004. The numbers correspond to locations on **Figure 12**.

Table 12. Significant exploration and development wells in Wyoming, second through fourth quarters of 2004. Number corresponds to location on Figure 12.

	Company name	Well name/number	Location	Formation tested	Depth(s) interval(s) tested	Tested prod. (per day)	Remarks
1	Chevron Production USA	5-31M Chevron-Federal	SW SE sec 31, T19N, R119W	Mission Canyon Ls. Lodgepole Ls.	14,414-15,646	14.2 MMCF	Development well in Whitney Canyon-Carter Creek Field
2	Ultra Resources	10-9D Warbonnet	NW SE sec 9, T30N, R108W	Lance Fm.	8609-13,254 several intervals	9.4 MMCF	New producer on Pinedale anticline in the Warbonnet area
	Ultra Resources	9D-4D Warbonnet	SE SE sec 4, T30N, R108W	Lance Fm.	8406-13,388 20 intervals	8.0 MMCF 126 BBL cond 416 BBL H_2O	New producer on Pinedale anticline in the Warbonnet area
	Ultra Resources	5-10D Warbonnet	NW NW sec 10, T30N, R108W	Lance Fm.	8491-13,478 19 intervals	8.5 MMCF	New producer on Pinedale anticline in the Warbonnet area
	Ultra Resources	3-3 Warbonnet	NE NW sec 3, T30N, R108W	Lance Fm.	8837-13,485 16 intervals	6.5 MMCF 65 BBL cond 162 BBL H_2O	New producer on Pinedale anticline in the Warbonnet area
	Ultra Resources	6-4 Warbonnet	SE NW sec 4, T30N, R108W	Lance Fm.	8526-13,356	8.6 MMCF 83 BBL cond 734 BBL H_2O	New producer on Pinedale anticline in the Warbonnet area
	Ultra Resources	16-4 Riverside	SE SE sec 4, T31N, R109W	Lance Fm.	10,095-13,180	13.2 MMCF 95 BBL cond 393 BBL H_2O	New producer on Pinedale anticline
	Shell Rocky Mountain Production	8-11 Vible	SE NE sec 11, T31N, R109W	Lance Fm.	10,610-13,248 eight intervals	11.1 MMCF 135 BBL H_2O	New producer on Pinedale anticline
	Shell Rocky Mountain Production	13-11D Jensen	NE SW sec 11, T31N, R109W	Lance Fm.	undisclosed intervals	12.2 MMCF	New producer on Pinedale anticline
	Shell Rocky Mountain Production	12-11D Jensen	NE SW sec 11, T31N, R109W directionally drilled from same drillpad as 13-11D Jensen	Lance Fm.	undisclosed intervals	4.8 MMCF	New producer on Pinedale anticline
	Shell Rocky Mountain Production	7-13 Riverside	SW NE sec 13, T31N, R109W	Lance Fm.	19 intervals above 13,397	18.0 MMCF	New producer on Pinedale anticline
	Yates Petroleum	2 Blue Rim-State	NW NE sec 16, T30N, R108W	Lance Fm. Mesaverde Fm.	9420-13,315 37 intervals	6.3 MMCF 85 BBL cond 114 BBL H_2O	New producer on Pinedale anticline
	Yates Petroleum	8 Blue Rim-State	SE NE sec 16, T30N, R108W	Lance Fm. Mesaverde Fm.	10,639-13,442 5 intervals	4.9 MMCF 56 BBL cond 208 BBL H_2O	New producer on Pinedale anticline
	Anschutz Petroleum	12-16 Gannett	NW SW sec 16, T33N, R109W	Lance Fm.	8579-14,638 19 intervals	3.3 MMCF 29 BBL cond	New producer on Pinedale anticline
3	Cabot Oil & Gas	32-14 Osbourne Spring Unit	SE SW sec 32, T26N, R97W	Almond Fm. Ericson Ss.	12,332-12,420 12,801-12,971	460 MCF 11 BBL H_2O	New discovery, 5 miles southwest of Lewis production at Picket Lake Field
4	Cabot Oil & Gas	20-29 Wind Dancer Unit	NW NE sec 29, T24N, R96W	Lewis Sh. Almond Fm.	10,746-10,818 10,878-10,916 11,206-11,328 11,401-11,453	1.4 MMCF 48 BBL H_2O	Confirmation well for Wind Dancer Unit discovery
	Cabot Oil & Gas	40-21 Wind Dancer Unit	SW SW sec 28, T24N, R96W	Lewis Sh. Almond Fm.	11,047-11,090 11,381-11,580	3.3 MMCF 5.6 BBL cond	New producer for Wind Dancer Unit
	Cabot Oil & Gas	40-28 Wind Dancer Unit	NE SW sec 28, T24N, R96W	Lance Fm. Fox Hills Ss.	four intervals 8182-9674	1.8 MMCF	New producer for Wind Dancer Unit
	Cabot Oil & Gas	40-28X Wind Dancer Unit	NW SW sec 28, T24N, R96W	Lewis Sh. Almond Fm.	10,848-10,882 11,173-11,398	1.5 MMCF 27 BBL H_2O	New producer for Wind Dancer Unit
5	BP America Production	27-1 Luman	SW SW sec 27, T22N, R95W	Mesaverde Gp.	10,287-10,417 10,466-10,598	1.6 MMCF 30 BBL cond 73 BBL H_2O	New wildcat discovery
6	Anadarko E & P	17 Higgins Unit	NW NW sec 22, T18N, R98W	Weber Ss.	17,576-17,951 17,964-17,974	1.5 MMCF 65 BBL H_2O	New producer in Table Rock Field
	Chevron USA	126 Table Rock Unit	SW NE sec 30, T19N, R97W	Weber Ss.	17,700-17,929 18,090-18,100	13.6 MMCF	New producer in Table Rock Field
7	BP America Production	3-1 Two Rim South	SW NW sec 3, T17N, R95W	Mesaverde Gp.	11,237-11,370	2.5 MMCF 3 BBL cond 389 BBL H_2O	New wildcat discovery
	BP America Production	19-4 South Dug Springs Unit	SW SW sec 19, T17N, R95W	Mesaverde Gp.	12,656-12,988	1.2 MMCF 5 BBL cond 178 BBL H_2O	New wildcat discovery
8	BP America Production	3-1 Horseshoe Bend	SE NW sec 3, T16N, R94W	Mesaverde Gp.	10,315-10,399 10,513-10,709	1.7 MMCF 1 BBL cond 62 BBL H_2O	New producer on the southern flank of Wild Rose Field
9	Samson Resources	40-6 Blue Haystack Unit	NW SE sec 6, T13N, R93W	Almond Fm.	11,758-11,768 11,856-11,874	1.0 MMCF 11 BBL H_2O	New wildcat discovery
10	Yates Petroleum	1 Peach Flat-State	C NE sec 36, T15N, R92W	Mesaverde Gp.	three intervals 6605-7188	3.3 MMCF 5 BBL cond 30 BBL H_2O	New producer in Blue Gap Field
11	BP America Production	23-1 Fivemile	SW SW sec 23, T21N, R93W	Mesaverde Gp.	three intervals 10,774-11,183	4.1 MMCF 13 BBL cond	New producer in Five Mile Gulch Field
	BP America Production	15-1 Fivemile	SW NW sec 15, T21N, R93W	Mesaverde Gp.	two intervals 11,090-11,407	334 MCF 2 BBL cond	New producer in Five Mile Gulch Field
12	BP America Production	11-1 Monument Lake	NW NW sec 11, T22N, R93W	Mesaverde Gp.	12,420-12,546 12,598-12,731	1.7 MMCF 9 BBL cond 101 BBL H_2O	New wildcat discovery
	BP America Production	27-1 Monument	SW SW sec 27, T22N, R93W	Lewis Sh. Mesaverde Gp.	10,944-10,954 11,438-11,448 11,582-11,727	703 MCF 25 BBL cond 92 BBL H_2O	New wildcat 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, April 2005.*

Table 12. Significant exploration and development wells in Wyoming, second through fourth quarters of 2004. Number corresponds to location on Figure 12.

	Company name	Well name/number	Location	Formation tested	Depth(s) interval(s) tested	Tested prod. (per day)	Remarks
12	BP America Production	29-1 Buck Draw	NW NW sec 29, T21N, R92W	Mesaverde Gp.	11,072-11,194 11,416-11,490	1.4 MMCF 3 BBL cond 168 BBL H_2O	New wildcat discovery
13	Bill Barrett Corporation	1 Stone Cabin Unit	NE SW sec 11, T34N, R87W	Muddy Ss.	13,130-13,156	8.8 MMCF 283 BBL cond 2 BBL H_2O	Discovery on the Stone Cabin Unit about 1 mile NE of Wallace Creek Field
14	Bill Barrett Corporation	22-15 Stone Cabin Unit	SE NW sec 15, T35N, R87W	Lance Fm. Meeteetse Fm.	7590-7596 7712-7724 7934-7944	605 MCF 5 BBL cond 17 BBL H_2O	Southernmost producer in Cooper Reservoir Field
15	Marathon Oil	61 Spring Creek South	NW NW sec 13, T49N, R102W	Phosphoria Fm. Tensleep Ss. Amsden Fm./ Darwin Ss. Madison Ls.	3710-3730 3870-4116 4139-4467 4534-4680	428 BBL oil 2771 BBL H_2O	Infill well in Spring Creek South Field
	Marathon Oil	63 Spring Creek South	NW NW sec 13, T49N, R102W	Phosphoria Fm. Tensleep Ss.	4046-4061 4205-4395	415 BBL oil 1557 BBL H_2O	Infill well in Spring Creek South Field
	Marathon Oil	62 Spring Creek South	NW NW sec 13, T49N, R102W	Tensleep Ss.	4120-4305	120 BBL oil 299 BBL H_2O	Infill well in Spring Creek South Field
	Marathon Oil	19 Phelps	SW SE sec 2, T49N, R102W	Phosphoria Fm. Tensleep Ss.	3808-3828 3951-4169	280 BBL oil 550 BBL H_2O	Infill well in Spring Creek South Field
	Marathon Oil	22 Phelps	NW NE sec 11, T49N, R102W	Tensleep Ss.	3798-3950	220 BBL oil 500 BBL H_2O	Infill well in Spring Creek South Field
16	Thermo Co.	11-1 Manigault	SW SE sec 11, T56N, R75W	Muddy Ss.	7670-7695	337 BBL oil 117 MCF	Offset to Thermo's 1996 1 CKS discovery well
17	Ballard Petroleum	44-36 Longreach-State	SE SE sec 36, T55N, R70W	Minnelusa Fm.	7236-7266	400 BBL oil 20 MCF	Wildcat discovery
18	Duncan Oil	1 Dry Gulch Unit-Federal	SW SW sec 22, T49N, R72W	Minnelusa Fm.	10,553-10,562	309 BBL oil	New producer in Dry Gulch Field
19	Stone & Wolf LLC	17-5 CS SW-Federal	SW NW sec 17, T34N, R66W	Muddy Ss.	8385-8406	50 BBL oil 100 MCF 7-hr. flow test	Exploratory test near abandoned Hat Creek Field

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, April 2005.*

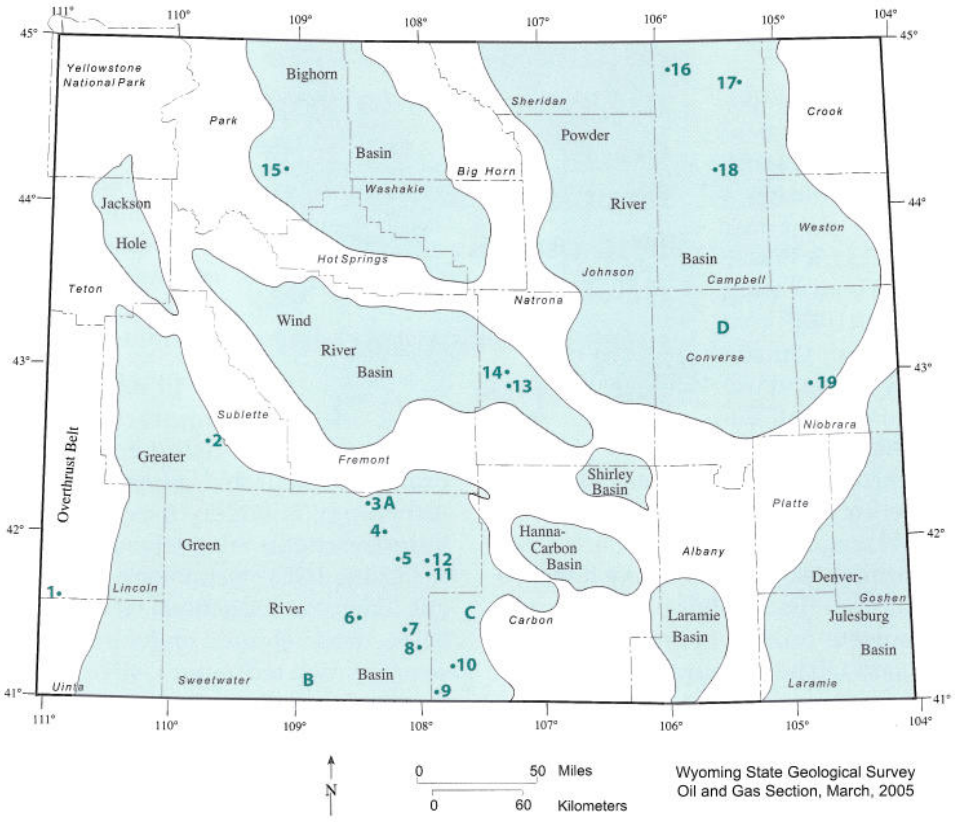


Figure 12. Oil and gas exploration and development activities in Wyoming during the second and third quarters of 2004. Numbers are those used in Table 12. Letters indicate coalbed methane developments described in the Coalbed Methane Update. Locations are approximate and may represent more than one well location or project.

Coal Update

Robert M. Lyman, Wyoming PG-656

Staff Geologist–Coal, Wyoming State Geological Survey

Coal production in Wyoming for the first three quarters of 2004 was about 2.6% higher than in 2003 as we predicted earlier, but a surge in coal deliveries in the last quarter of 2004 eclipsed all projections for the final yearly total. A new production record of 395.7 million short tons was set for 2004, representing an annual increase of about 5.1%. A minor amount of underground coal was mined in Sweetwater County in 2004, as Bridger Coal Company began developing a new longwall operation. This is the first underground production in the state in three years.

Average coal prices for 2004 were slightly higher than those in 2003, reflecting the strong performance of coals from the Powder River Coal Field throughout most of the year. In addition to the increased revenues to the State of Wyoming from higher valuations on sold coal, five federal coal lease sales in the second, third, and fourth quarters netted the State bonus bids totaling $686.8 million. Payments of the bonus bids are usually made over a five-year period, so the State will be receiving substantial ($894 million) revenues from these and other lease sales in the next few years.

A number of electric utility companies in the second and third quarters of 2004 announced plans to use Wyoming coal for various projects, including a 1000-megawatt (MW) power plant near Gillette proposed by Basin Electric Power Cooperative. Detroit Edison is increasing its use of Powder River Basin (PRB) coal in blending with eastern coal; Omaha Public Power District is planning to use PRB coal in a new 663-MW plant; the City of Hastings (Nebraska) Utilities will use PRB coal at their proposed 220-MW plant; Dynergy Midwest Generation is switching from Colorado to PRB coal at their 445-MW plant at Havana, Illinois; CONSOL Energy is moving PRB coal to Northern Appalachia where it will be blended with eastern coal from the Pittsburg #8 seam; and finally, some western concrete producers are considering a switch from Colorado and Utah bituminous coal to PRB coal.

. . .much of the petroleum we now import will become too expensive to rely on. In 2002, the U.S. imported nearly 40 Btu quads. . .of the 98.1 Btu quads of energy consumed for our needs.

The future of Wyoming coal, Part II

China's growth in its power needs is drawing much attention in world energy circles. With the Chinese economy growing at over 10% a year, the country is facing serious power deficiencies; 23 of their 24 provinces expect power shortages in the short term. About 55% of the power produced is used in the industrialized southeastern part of China. Because of that load, the Chinese power industry is showing signs of stress. Residential needs of the country are being underserved even though they are adding 30 to 40 gigawatts (GW) of power generation per year to meet demand. The consumption of coal used for electrical generation is growing by 60 to 70 million short tons per year. Because many of the Chinese generating plants are new, the country has the most efficient assemblage of power plants in the world. China is well endowed with coal resources, but most of the coal is not of export quality. While the country will most likely meet its own demand for coal, other fossil fuels (like petroleum-based products) for the Chinese economic vitalization will have to be purchased from the same countries currently supplying the U.S.

Our national energy policy makers should encourage clean coal gasification and liquefaction plants in this country because much of the petroleum we now import will become too expensive to rely on. In 2002, the U.S. imported nearly 40 Btu quads (40 Btu's with 15 zeros following it) of the 98.1 Btu quads of energy consumed for our needs. Our country's electric utilities face a dilemma. Intuitively, our national energy policy should call for increased independence from foreign oil, gas, and coal supplies, but the use of our plentiful, indigenous coal reserves is especially restricted by increasingly stringent environmental regulations. Meanwhile, high energy prices continue to damage the U.S. economy.

In addition to coal gasification and liquifaction, other new technologies using coal should be advanced. For example, integrated gasification combined cycle (IGCC) technology is widely used in the chemical and refining industries but is relatively new in the electric power industry. Using IGCC technology, coal is turned into a synthetic gas. Emission reductions when this gas is burned are well below those required under the Clean Air Act. Using carbon sequestration techniques, 90% of the carbon dioxide can be removed from the emission stream.

Unfortunately for Wyoming coal, the most commercially advanced IGCC designs work best with eastern high-sulfur, low-moisture, bituminous coal. This poses a threat to Wyoming's future share of the coal market. Hoping to provide IGCC technology for lower rank coal, the Electric Power Research Institute is embarking on a phase of studies to address this future challenge. Hopefully, the western coal industry will support this vital research.

Now is the time for Wyoming coal to further serve the country's energy needs by assuming a leading role to develop emerging technologies. Wyoming has the coal resources to meet this challenge but there appears to be a lack of understanding (and education) about this country's energy supply and consumption and possible solutions to the problems.

Production and prices

Our earlier projection of a 2.6% increase in coal production from 2003 to 2004 has been revised upward. In October 2004, the State of Wyoming's Consensus Revenue Estimating Group (CREG) forecast a 4.57% increase in 2004 (**Table 1**) but final production figures from the Wyoming State Inspector of Mines indicate a 5.09% increase (**Table 13**). The 395.7 million short tons produced in Wyoming in 2004 sets a new yearly production record. Some of the anticipated growth in production during the last two months of 2004 may have been hampered by problems moving coal from the PRB. The CREG forecast calls for an additional 2% increase in 2005 and a 1% increase in 2006 through 2010 and **Table 13** reflects those increases based on the new production figures for 2004. Most of the increased production will come from the PRB mines and Campbell County with modest increases in southern Wyoming counties (**Table 13** and **Figure 13**).

Coal deliveries through September 2004 were about 2.8% ahead of those through September 2003, but increased deliveries (despite the railroad bottlenecks) the last three months of 2004 were substantially higher than in 2003 (**Table 14**). Monthly deliveries for October and December 2004 were the highest ever (**Figure 14**). It appears that the portion of Wyoming coal sold on the spot market is becoming a smaller percentage (10 to 12% in 2004 compared to 18 to 20% in earlier years) of the state's monthly coal shipments (**Figure 15**). This may indicate that transportation is becoming problematic for some spot customers while the higher-priced contract coal (**Figure 15**) receives priority by both the producers and the railroads.

Based on stronger than expected coal prices during 2004, CREG's latest forecast (October 2004) (**Table 2** and **Figure 16**) is about $0.90 per short ton higher than in October 2003 (see *Wyoming Geo-notes No. 78*, November 2003). For 2004 the average price of coal is forecast at $6.88 per short ton and by 2006, the average price will be over $7.00 per short ton. Overall higher energy prices have eliminated the decreases in coal prices predicted earlier and the average price of PRB coal (**Table 15** and **Figure 16**), which ultimately controls the average coal prices statewide, remains high.

Spot market prices for PRB coal in 2004 remained steady, rising modestly at the end of the first quarter then falling slightly at year's end. Spot prices for 8400-Btu coal began the year at $5.45 per short ton, topping out at $5.71 per short ton in mid-April and then settling back to the $5.30 per short ton by the year end (**Figure 17**). Average prices for 8800-Btu coal began 2004 at $6.53 per short ton and by the end of March was being quoted at nearly $7.32 per short ton compared to $6.18 per short ton a year earlier. By the end of 2004, the higher Btu product was averaging about $6.24 per short ton. The average spot price of all PRB coal at the end of 2004 was $5.77 per short ton.

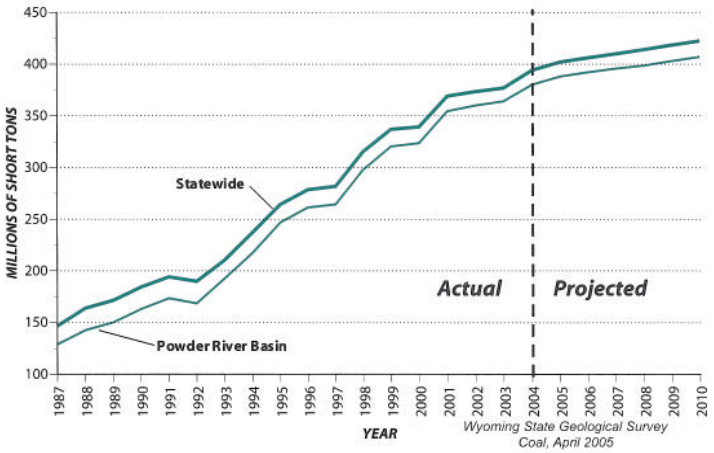


Figure 13. Annual coal production from Wyoming and the Powder River Basin (1987 through 2004) with forecasts to 2010. Sources: Wyoming State Inspector of Mines (1987 through 2004), modified from CREG (2005 through 2010), and the Wyoming State Geological Survey.

Table 13. Wyoming coal production by county[1,2] (in millions of short tons), from 1999 to 2004 with forecasts to 2010.

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Powder River Basin												
Campbell County	294.3	299.5	329.5	332.8	334.1	351.9	360.0	364.0	367.5	370.5	374.5	378.5
Converse County	25.6	23.6	24.6	26.8	29.5	29.7	29.8	30.0	30.0	30.0	30.0	30.0
Sheridan County	M	M	0.0	0.0	0.0	M	M	M	M	M	M	M
Subtotal	319.9	323.1	354.1	359.6	363.6	381.6	389.8	394.0	397.5	400.5	404.5	408.5
Southern Wyoming												
Carbon County	2.7	2.0	0.5	0.7	0.3	0.2	0.3	0.5	1.0	2.0	2.0	2.0
Sweetwater County	9.4	10.0	9.5	8.6	8.5	9.4	9.0	9.0	9.0	9.0	9.0	9.0
Lincoln County	4.3	3.7	4.5	4.2	4.1	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Subtotal	16.4	15.7	14.5	13.5	12.9	14.1	13.8	14.0	14.5	15.5	15.5	15.5
Total Wyoming[3]	**336.5**	**338.9**	**368.6**	**373.1**	**376.5**	**395.7**	**403.6**	**408.0**	**412.0**	**416.0**	**420.0**	**424.0**
Annual change	**6.9%**	**0.7%**	**8.8%**	**1.2%**	**0.9%**	**5.1%**	**2.0%**	**1.0%**	**1.0%**	**1.0%**	**1.0%**	**1.0%**

[1]Reported tonnage from the Wyoming State Inspector of Mines (1999 through 2004). [2]County estimates by the Wyoming State Geological Survey, May 2004 for 2005 through 2010. Totals may not agree because of independent rounding. [3]Modified from CREG's Wyoming State Government Revenue Forecast, October, 2004. M=minor tonnage (less than a million short tons). *Wyoming State Geological Survey, Coal Section, April 2005.*

Table 14. Estimated monthly coal deliveries from Wyoming's mines in short tons (January, 2000 through December, 2004).

	2000		2001		2002		2003		2004	
	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative
January	27,773,610	27,773,610	27,743,000	27,743,000	28,406,666	28,406,666	31,450,642	31,450,642	32,870,561	32,870,561
February	25,594,109	53,367,719	27,827,000	55,570,000	30,041,748	58,448,414	28,113,877	59,564,519	29,881,411	62,751,972
March	28,262,696	81,630,415	33,739,000	89,309,000	33,409,797	91,858,211	30,310,040	89,874,559	28,411,135	91,163,107
April	25,549,039	107,179,454	27,302,000	116,611,000	27,534,057	119,392,268	30,656,600	120,531,159	29,773,501	120,936,608
May	26,222,515	133,401,969	27,752,000	144,363,000	34,704,299	154,096,567	31,631,441	152,144,600	35,899,223	156,835,831
June	25,085,516	158,487,485	33,968,000	178,331,000	26,674,488	180,771,055	30,797,925	182,942,525	30,523,471	187,359,302
July	28,881,862	187,369,348	29,200,000	207,531,000	27,885,210	208,656,265	31,608,733	214,551,258	37,459,000	224,818,302
August	29,075,295	216,444,642	27,662,000	235,193,000	35,670,535	244,326,800	32,402,820	246,954,078	31,303,000	256,121,302
September	25,865,389	242,310,032	35,369,000	270,562,000	32,234,471	276,561,271	32,169,561	279,123,639	30,685,000	286,806,302
October	26,441,615	268,751,646	29,869,000	300,431,000	26,101,957	302,663,228	32,983,610	312,107,249	38,821,000	325,627,302
November	27,400,246	296,151,892	29,308,000	329,739,000	32,767,619	335,430,847	31,132,084	343,239,333	30,153,000	355,780,302
December	28,300,773	324,452,665	29,984,000	359,723,000	26,476,240	361,907,087	32,362,439	375,601,772	37,786,000	393,566,302
Total Utility Tonnage[1]	**324,452,665**		**359,723,000**		**361,907,087**		**375,601,772**		**393,566,302**	
Total Tonnage Other[2]	**14,399,483**		**8,955,135**		**11,288,344**		**963,475**		**2,158,976**	
Total Tonnage Produced[3]	**338,852,148**		**368,678,135**		**373,195,431**		**376,565,247**		**395,725,278**	

[1]From Federal Energy Regulatory Commission (FERC) Form 423 for 1998; FERC Form 423 as modified by WSGS for 2000 through December 2004. [2]Includes estimates of a residential, industrial, and exported coal. [3]Wyoming State Mine Inspector's Annual Reports. *Wyoming State Geological Survey, Coal Section, April 2005.*

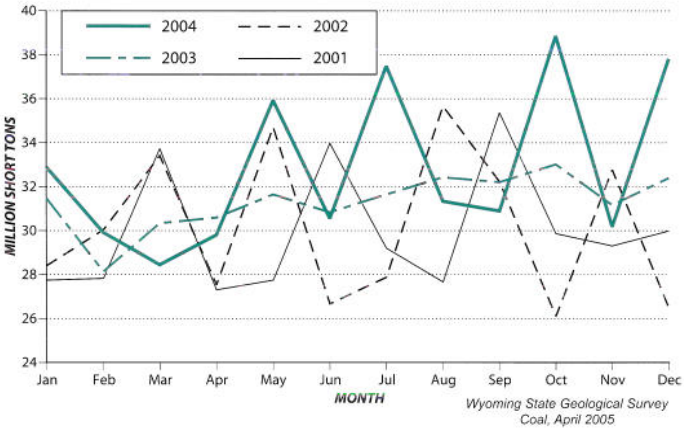


Figure 14. Reported monthly deliveries from Wyoming coal mines (2001 through December 2004). From the Federal Energy Regulatory Commission (FERC) Form 423 as adjusted by the Wyoming State Geological Survey.

Developments in the Powder River Basin

Arch Coal's Black Thunder mine announced that they "achieved a one-billion-ton shipment milestone on Friday, Dec. 17, 27 years after the mine's first coal shipment on Dec. 14, 1977." Arch further stated, "Today, Black Thunder produces nearly 10% of the U.S. coal supply. That's enough coal to provide electricity to 5.8 million American households... We're proud to be the first coal mine to ever achieve this milestone" (Coal Trader, 12/21/04).

After successfully defending its acquisition of Triton Coal, Arch completed a public offering of 7,187,000 shares of its common stock at a price of $33.85 per share in October. Investigators with the U.S. Securities and Exchange Commission (SEC) had challenged the acquisition. The nation's second leading coal producer will use $230.6 million from the offering to repay money used under a revolving credit facility it used to finance the $364 million Triton acquisition. Proceeds from the offering also will be used to make the first annual lease bonus payment for their recently acquired Little Thunder coal lease (Coal Trader, 10/29/04).

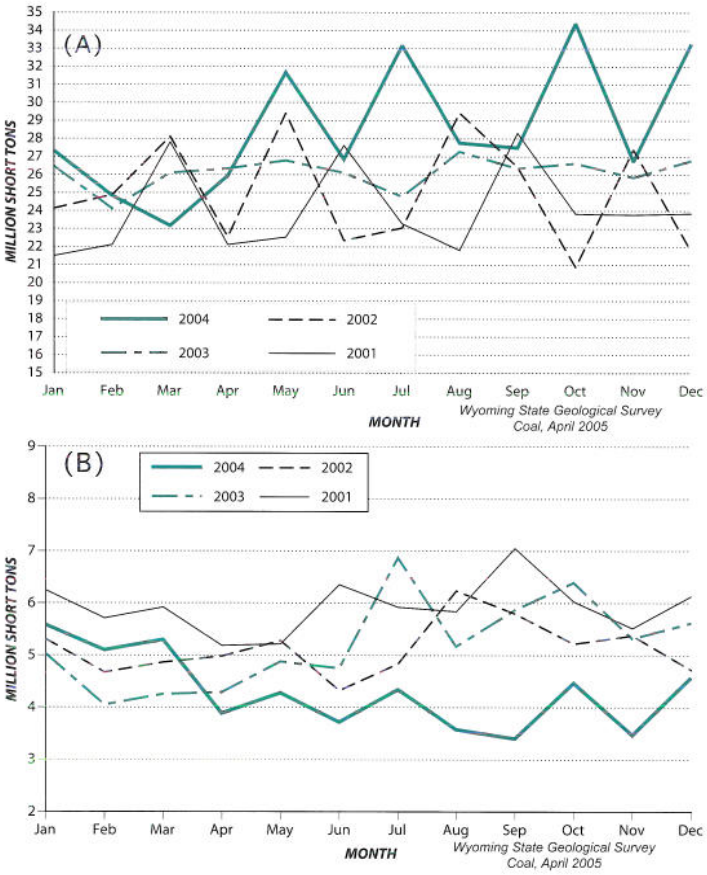


Figure 15. Monthly coal deliveries from Wyoming (2001 through December, 2004). (A) Coal sold on contract and (B) coal sold on the spot market. From the Federal Energy Regulatory Commission (FERC) Form 423 as modified by the Wyoming State Geological Survey.

In a briefing with the SEC in early November, Arch revealed it was forced to slow production at its Black Thunder mine "due to high inventory levels stemming from insufficient rail service." According to Arch, the rail disruptions initially resulted from inadequate staffing levels at the railroads, equipment shortages, and an unexpected increase in overall rail shipments. While the situation improved during

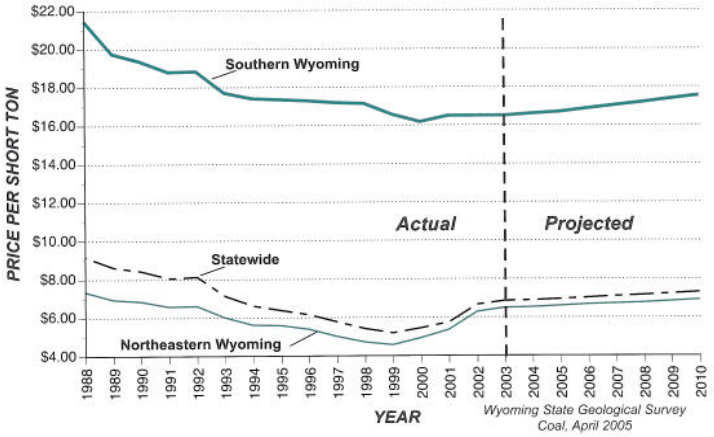


Figure 16. Average prices paid for Wyoming coal by producing area (1988 through 2003) with forecasts to 2010. Sources: U.S. Energy Information Administration (1988 through 1990); Wyoming Department of Revenue(1991 through 2003); and CREG (2004 through 2010).

the third quarter, Arch anticipated that "challenges with rail service" would persist for the balance of 2004 (Coal Trader, 11/12/2004).

Kfx Inc. has received the required air emissions permit from the Wyoming Department of Environmental Quality, allowing the company to proceed with construction on its mine-mouth facility at its recently acquired Fort Union mine near Gillette. Kfx plans to complete a 750,000- short-ton-per-year enhanced coal facility by mid-2005 (Coal Trader, 11/12/2004).

Congratulations to Peabody Energy for being named for the second time "Coal Company of the Year" at the Platts Global Energy Awards program held in New York City on December 10, 2004. Although Platts sponsors the annual award, independent judges make the determination. Peabody's North Antelope/Rochelle mine complex also received the coveted Sentinels of Safety Award from the U.S. Mine Safety and Health Administration (MSHA) for operating the nation's safest large surface coal mine in 2003. Employees of the mine operated 1.6 million hours in 2003 without a lost time accident, a new record for a U.S. surface mine. In addition, the mine was given the Safe SAM Award from the

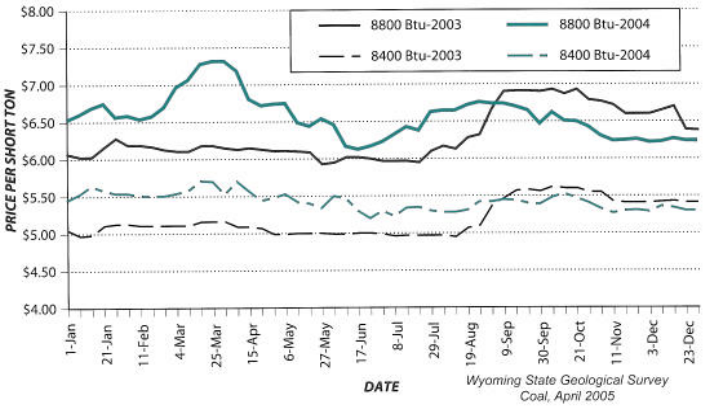


Figure 17. Wyoming Powder River Basin coal spot price watch (January 1, 2003 through December 31, 2004). Modified from Coal Daily's spot market index, and U.S. Coal Review spot market price index.

Table 15. Breakdown of average prices paid for coal from northeastern Wyoming, southern Wyoming, and Wyoming as a whole (1988 through 2003) with forecast to 2010.

	Year	Northeastern	Southern	Statewide
Actual	1988	$7.35	$21.45	$9.16
	1989	$6.94	$19.76	$8.63
	1990	$6.86	$19.36	$8.43
	1991	$6.58	$18.81	$8.06
	1992	$6.61	$18.84	$8.13
	1993	$6.02	$17.72	$7.12
	1994	$5.62	$17.42	$6.62
	1995	$5.60	$17.35	$6.38
	1996	$5.40	$17.30	$6.15
	1997	$5.03	$17.19	$5.78
	1998	$4.73	$17.15	$5.41
	1999	$4.57	$16.58	$5.19
	2000	$4.93	$16.19	$5.40
	2001	$5.36	$16.50	$5.75
	2002	$6.28	$16.50	$6.66
	2003	$6.50	$16.50	$6.85
Forecast	2004	$6.52	$16.60	$6.88
	2005	$6.60	$16.70	$6.95
	2006	$6.67	$16.87	$7.02
	2007	$6.72	$17.04	$7.09
	2008	$6.77	$17.21	$7.16
	2009	$6.84	$17.38	$7.23
	2010	$6.91	$17.55	$7.30

Statewide data for 1988 through 1990 are from reports by the U.S. Department of Energy's Energy Information Administration; data for 1991 through 2003 are derived from Wyoming Department of Revenue information; estimates for 2004 through 2010, and all regional breakdowns by the *Wyoming State Geological Survey, Coal Section, April 2005.*

Wyoming State Inspector of Mines for operating the state's safest mine in 2003 (U.S. Coal Review, 10/4/04).

Coal exchange and lease sales

The U.S. Bureau of Land Management (BLM) has approved the land-for-coal exchange with Pittsburgh & Midway Coal Company (P&M). The company wanted to swap some of their other federal coal properties (leases) for 1234 acres of federal land and coal in Sheridan County. The deal gives the BLM control of over 5859 acres in various places in Wyoming and P&M control of Sheridan County properties containing an estimated 84.2 million short tons of recoverable coal reserves (see details in *Wyoming Geo-notes No. 81*, November 2004, p. 18). P&M expects to hire a consultant to help them determine if it should enter into a joint mining arrangement with CONSOL Energy, mine the coal itself, or hire a contract miner for the project (U.S. Coal Review, 12/6/2004).

There were five federal coal lease tracts in the PRB offered for sale by the BLM in 2004 under their lease-by-application (LBA) process. The first tract, NARO South, was auctioned on June 28 (see details in *Wyoming Geo-notes No. 81*, November 2004, p. 18) and brought the highest price ever, $0.92 per short ton for a total bonus bid of $274.08 million, of which the State of Wyoming receives half (**Table 16**). In the August 31 lease sale, Peabody Energy's bid for the NARO North LBA was rejected, but on December 29, 2004, the tract was re-offered (see details below). **Table 16** illustrates how the value of the PRB's coal reserves has appreciated since the LBA process began.

On September 22, Arch Coal bid $611 million for the 5084-acre Little Thunder LBA tract. The lease, located next to the company's Black Thunder mine, contains roughly 719

million short tons of recoverable coal. With the addition of these reserves, the company now controls 2.2 billion short tons of PRB coal, including 1.6 billion short tons that can be mined from their existing Black Thunder operation. The accepted bid calculates to a price of $0.85 per short ton. Over the next five years Wyoming will receive $305.5 million as the State's share of the new lease bonus (U.S. Coal Review, September 9, 2004).

Peter Kiewit & Sons successfully submitted the winning bid for the West Hay Creek LBA in the November 17 lease sale. Triton Coal filed the LBA in August 2000 to add reserves to the Buckskin mine. Buckskin was acquired by Kiewit early this year as a spin off from Arch's earlier Triton acquisition. The lease tract consists of 921 acres and contains estimated recoverable coal reserves of nearly 142.7 million tons. The primary coal seam is the 54- to 68-foot-thick Canyon; the overlying Anderson coal seam consists of 16 to 19 feet of coal. The interburden between the Anderson and Canyon ranges from 29 to 85 feet thick. Maximum overburden above the Anderson ranges from 32 to 275 feet. Projected as-received coal quality of the reserves is 8140 Btu per pound, 0.41% sulfur, 5.32% ash, and 32.1% moisture. The company's winning bid of $42.8 million, or $0.30 per short ton, surprised some observers after recent bids on other LBAs garnered $0.92 per short ton (Coal Trader, 11/18/2004).

Table 16: Historical price per ton paid for Powder River Basin LBA tracts (September 1991 through February 2005).

LBA	Date sold	Effective date	$/ton	Wyoming's share
West Roundup	2/16/05	4/1/05	0.971	$158,845,000.00
NARO North	12/29/04	3/1/05	0.920	$149,571,892.50
West Antelope	12/5/04	3/1/05	0.750	$73,155,500.00
Little Thunder	9/22/04	3/1/05	0.850	$305,499,974.90
West Hay Creek	11/17/04	1/1/05	0.301	$21,404,700.00
NARO South	6/28/04	9/1/04	0.920	$137,058,842.00
North Jacobs Ranch	1/16/02	5/1/02	0.706	$189,752,326.00
Horse Creek	9/7/00	12/1/00	0.330	$45,610,060.35
Thundercloud	10/1/98	1/1/99	0.384	$79,000,004.25
Powder River	6/30/98	8/1/98	0.206	$54,798,250.00
North Rochelle	9/25/97	1/1/98	0.194	$15,288,170.00
Antelope	12/4/96	2/1/97	0.150	$4,527,300.00
Eagle Butte	4/5/95	8/1/95	0.111	$9,235,200.00
West Rocky Butte	1/7/93	1/1/93	0.291	$8,250,000.00
North Antelope/Rochelle	9/28/92	10/1/92	0.216	$43,493,882.50
West Black Thunder	8/12/92	10/1/92	0.168	$35,954,641.35
Jacobs Ranch	9/26/91	10/1/91	0.136	$10,057,465.00

Source: U.S. Bureau of Land Management, February 2005.

In the December 5 lease sale, Kennecott Energy's Antelope Coal Company bid $146.3 million or $0.75 per short ton for the 2809-acre West Antelope LBA. The tract contains an estimated 195 million short tons of mineable coal in Converse County. The BLM accepted the bid. The State of Wyoming's share of the bonus money will be $73.2 million (**Table 16**) paid in equal payments made over the next five years (Coal Outlook, 12/20/04).

On December 29, Peabody Energy won the NARO North LBA at the BLM lease auction. Late in August when the coal tract was first offered, Peabody's $237.5 million bid was rejected as failing to meet the minimum set for the coal property. At the resale, Peabody successfully bid $299.2 million for the tract or approximately $0.92 per short ton of mineable coal. The new lease, located adjacent to the company's North Antelope/Rochelle mine complex contains some of the best coal in the southern PRB. The average as-received heat content is estimated at 9000 Btus per pound; sulfur runs approximately 0.55 pounds per million Btus. With the new coal lease, Peabody now controls 3.3 billion short tons of PRB coal. The company now is looking to build a new mine to better exploit their new PRB reserves and other un-leased tracts adjacent to the new LBA (U.S. Coal Review, 1/10/05).

The BLM's LBA system began processing the bonus lease program in 1989. Since the first bonus payment was received by Wyoming in 1991, through 2004 the state has received nearly $447.5 million from the PRB lease sales (**Table 17**). From 2005 through 2009, Wyoming is set to receive an additional $894 million in PRB coal lease bonus money. Total revenue to Wyoming from the LBA sales over the period 1991 to 2009 will total over $1.3 billion.

Developments in southern Wyoming

Sweetwater County's Bridger mine entered the world of underground mining in the fourth quarter of 2004. With permits in place and coal reserves successfully acquired, the company began, via continuous miners, development of its planned longwall operation. Reports from mine personnel indicate that the developmental mining is proceeding well. The Wyoming State Inspector of Mines said the new underground works reported 2004 production totaling 44,000 short tons, the state's first deep mine production in over three years.

The New Stansbury Coal Co. has purchased the Stansbury mine near Rock Springs from Rock Springs Royalty Co., including the mine assets, a coal lease, a surface-use license, and mining permits. Renamed the Little Patriot mine, it has a projected mine life of more than 20 years. The as-received coal quality specifications are believed to be 11,000 Btus per pound, 6% ash, and 0.95% sulfur. First-year production from the underground mine is targeted for 750,000 short tons and within two years the mine hopes to be producing 3 million short tons annually (U.S. Coal Review, 9/27/04). It may be a while before the new mine begins operations, because no contracts for sale of the coal have been signed and the new operation reportedly is facing some other financing challenges.

Transportation developments

Principals of the Dakota Minnesota and Eastern (DM&E) railroad expansion into the Wyoming portion of the PRB believe construction should start in 2006 with completion in the first quarter of 2009. The railroad over the past several years has been working with local officials to allow heavy coal traffic through a number of South Dakota and Minnesota communities. So far, 54 of 56 municipalities through which DM&E will travel have signed agreements with the railroad. The City of Brookings, South Dakota and Rochester, Minnesota have not signed an agreement with the railroad. The DM&E said the City of Brookings is working in good faith with the railroad. Many citizens of Rochester, home of the

world-famous Mayo Clinic, continue to oppose coal traffic through their town (Coal Trader, 12/10/04).

NRG Energy has entered into a long-term transportation agreement with Burlington Northern Santa Fe Railroad (BNSF) and affiliates of American Commercial Lines to deliver PRB coal to the Big Cajun II power plant in New Roads, Louisiana. The contract begins in April 2005. The 1700-MW plant burns between 7 and 8 million short tons of the Wyoming coal annually (Coal Trader, 12/14/04).

American Electric Power (AEP) has agreed to transload PRB coal shipments from BNSF unit trains to barges via the Cook Coal Terminal in Metropolis, Illinois; the coal then will be barged to Kentucky Utilities' Ghent plant. Kentucky Utilities will pay AEP $1.35 per short ton for the service, which will run until the end of 2005 (Coal Trader, 12/17/04).

The BNSF railroad is beginning to investigate the increasing problem of coal dust contaminating their *ballast* (stone or gravel placed to provide a firm foundation for the track and to facilitate drainage). The railroad claims the ballast in their PRB line is becoming extremely clogged with coal dust, threatening its stability. The mines are concerned that the railroad may be looking at charging a 10 to 15% dust fee to cover the cost of ballast maintenance, which would add up to millions of dollars for the basin's coal customers (Coal Daily, 8/30/04).

Table 17: Wyoming revenue from Powder River Basin LBA bonus lease money (1991 through 2009).

Year	Annual payments	Historical cumulative	Future cumulative	Total cumulative
1991	$2,011,493.00	$2,011,493.00		$2,011,493.00
1992	$17,901,197.77	$19,912,690.77		$19,912,690.77
1993	$19,551,197.77	$39,463,888.54		$39,463,888.54
1994	$19,551,197.77	$59,015,086.31		$59,015,086.31
1995	$21,398,237.77	$80,413,324.08		$80,413,324.08
1996	$19,386,744.77	$99,800,068.85		$99,800,068.85
1997	$4,402,500.00	$104,202,568.85		$104,202,568.85
1998	$16,769,784.00	$120,972,352.85		$120,972,352.85
1999	$32,569,784.85	$153,542,137.70		$153,542,137.70
2000	$39,844,756.92	$193,386,894.62		$193,386,894.62
2001	$39,844,756.92	$233,231,651.54		$233,231,651.54
2002	$76,889,762.12	$310,121,413.66		$310,121,413.66
2003	$62,872,478.12	$372,993,891.78		$372,993,891.78
2004	$74,484,245.67	$447,478,137.45		$447,478,137.45
2005	$207,057,647.08		$207,057,647.08	$654,535,784.53
2006	$207,057,647.08		$414,115,294.16	$861,593,431.61
2007	$169,107,181.88		$583,222,476.04	$1,030,700,613.49
2008	$169,107,181.88		$752,329,657.92	$1,199,807,795.37
2009	$141,695,413.48		$894,025,071.40	$1,341,503,208.85

Wyoming State Geological Survey, Feburary 2005.

The Union Pacific Railroad (UP) expects to take delivery of 315 diesel-electric locomotives in the first half of 2005. The decision to buy the new low-emission locomotives will help the line satisfy Environmental Protection Agency (EPA) railroad Tier 2 emission regulations that begin in January 2005. The railroad said that currently about 35% of its 7861-unit locomotive fleet is certified under existing EPA Tier 0 and Tier 1 air regulations. The new locomotives will produce the same horsepower as the existing locomotives, but will reduce air emissions upwards to 40% (Coal Daily, 9/30/04).

The BNSF and UP are moving carefully in their shift to common tariff rates for PRB coal to avoid raising anticompetitive concerns. The two lines are responding to constrained capacity on their rail networks by increasing prices on a variety of commodities. Part of the railroads' strategy involves shifting coal customers from long-term contracts to tariff-based pricing systems. In July, Representative Jim Sensenbrenner (Republican-Wisconsin), chairman of the House Judiciary Committee, wrote Assistant Attorney General William Moschella, telling him that shippers are complaining the public pricing system "could raise anticompetitive concerns" and "additional investigation into competitive practices may be warranted" (Coal Daily, 12/15/04).

Regulatory and federal developments

The U.S. Department of Energy (DOE) released a solicitation for Phase II of its Regional Carbon Sequestration Partnerships Program. The solicitation will provide up to $100 million in federal funds over four years for partnerships of state agencies, private companies, universities, and national laboratories that will field-test and validate promising carbon sequestration technologies. The testing done in Phase II will be based on the recommendations from partnerships funded under the program's Phase I (Coal Trader, 12/15/04).

Pegasus Technology, in conjunction with Texas Genco, has been selected by the DOE for a project to advance mercury reduction at power plants. Under the clean-coal phase II of President Bush's 10-year Clean Coal Power Initiative, the Pegasus project will receive $6.1 million in federal funds or half the $12.2 million price tag of the study. The project will demonstrate the capability of sophisticated control processes and advanced sensor technologies to optimize mercury speciation and control from an existing 890-MW utility boiler in Jewett, Texas. The project will involve burning a blend of Texas lignite and PRB subbituminous coal (Coal Trader, 10/29/04).

Reliant Energy announced in November that it is preparing fourth quarter 2004 test burns of PRB coal at its Avon Lake, Ohio; Cheswick, Pennsylvania; and Newcastle, Pennsylvania, plants. The tests were scheduled because of Reliant's difficulties in getting delivery of coals (from other areas) for which it has existing contracts (Coal Outlook, 11/8/04).

The federal Abandoned Mine Land (AML) Program received a nine-month extension running through June 2005 from passage of a government funding bill in November. The bill includes language allowing federal officials to continue collection of the AML tax from coal producers that is intended to pay for the cleanup of abandoned mine sites (U.S. Coal Review, 11/29/04).

Market developments and opportunities

TXU Power announced in November that they would mothball a total of 2516 MW of gas-fired generation, comprising eight units of their system. The company said they also were considering repowering some of the targeted units with

coal. Most of the affected units have been used seasonally, and represent 25% of TXU's gas-fired generation capacity (Coal Outlook, 11/15/04).

Basin Electric Power Cooperative intends to build a single-unit, 100-MW coal-fired power plant in the Gillette area. The final site has yet to be selected, but current plans call for the plant to be operational by 2011. "Our intention is to locate it in close proximity to one of the mines," Basin Electric told the *Coal Trader*. Technologies being examined for the new plant include pulverized coal, circulating fluidized bed, and IGCC. The latter is more expensive than the other two technologies, but is recognized as cutting-edge, environmentally friendly technology (Coal Trader, 12/22/04).

PRB coal burns for Detroit Edison plants in 2004 are projected to increase by about 2 million short tons over those in 2003. The company cited that high prices of eastern coal have changed the economics of the various blends the utility employs at its generating plants (U.S. Coal Review, 12/13/04).

Omaha Public Power District (OPPD) has selected a consortium of contractors, known as Nebraska City Power Partners, to continue negotiations for permitting and constructing the 663-MW coal-fired Nebraska City 2 project. The plant is designed to provide power to OPPD and seven other public power entities that are participating in the project. Half the power output will serve OPPD customers; the other half will go to the remaining partners. This is the first large baseload project in 30 years for the utility. OPPD plans for the plant to consume Wyoming PRB coal (Coal Trader, 12/27/04).

Dynegy Midwest Generation is switching their 445-MW Havana generating plant in central Illinois from Colorado coal to PRB coal. The switch is scheduled to be completed by early 2005. Spokesman David Byford said the company is changing to PRB coal because of "lower costs and lower emissions" (Coal Trader, 11/10/04).

The City of Hastings (Nebraska) Utilities has been issued an air permit for a new 220-MW coal-fired generating plant to be built alongside their existing 77-MW Whelan plant. A consortium of Nebraska utilities and a Wyoming municipalities board are planning the plant. The plan calls for the $445-million unit to come into service by May 2012. The parties include in addition to Hastings Utilities, the Municipal Energy Agency of Nebraska, the Heartland Consumers Power District, OPPD, Grand Island Utilities, Nebraska City Utilities, and Consolidated Wyoming Municipalities Electric Power System Joint Powers Board (Coal Trader, 12/8/04).

Western concrete producers have begun to focus on PRB coal suppliers as an alternate to their Uinta Basin and Colorado suppliers because the producers are paying some of the highest prices for coal in their history. So far, no real switching has been made and the concrete manufacturers are concerned about placing further stress on the UP rail system, which has been extremely congested over the past year (Coal Weekly, 9/3/04).

CONSOL Energy is moving PRB coal to Northern Appalachia where it is reportedly blended with CONSOL's Pittsburgh #8 coal. CONSOL is taking the PRB coals to the Warrenton terminal on the Ohio River to reduce the sulfur in their eastern production. They plan to offer blends containing up to 20% PRB coal. Because many utilities continue to have difficulty getting Central Appalachian coal, many market observers believe there will be growing demand for a Pittsburgh #8/PRB blend (U.S. Coal Review, 9/20/04).

Table 18 tabulates some of the contract, spot sales, test burns, and solicitations for Wyoming coal, announced during the third and fourth quarters of 2004.

References cited

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

Stauffenberg, D.G., 2004, Annual report of the State Inspector of Mines of Wyoming for the year ending December 31, 2004: Office of the State Inspector of Mines, Rock Springs, 89 p.

Table 18. Marketing activities for Wyoming coal producers during the third and fourth quarters of 2004*.

Utility	Power Plant	Coal Mine/Region	Activity	Tonnage	Comments
City Utilities of Springfield	James River & Southwest	Kennecott Energy/PRB	C	1 mt/y for 3 years	Delivery in 2005-2007
Consumers Energy	System	PRB	Sp	200,000 t	Delivery in first quarter 2005
Empire District Electric	System	Arch Coal/PRB	Sp	29,000 t (2 trains)	Delivery in December 2004
FirstEnergy Generation	System	Arch Coal/PRB	C	2 mt/y for 6 years	Delivery in 2005-2010
FirstEnergy Generation	System	Kennecott Energy/PRB	C	2 mt/y for 6 years	Delivery in 2005-2010
FirstEnergy Generation	System	Peabody Energy/PRB	C	2 mt/y for 6 years	Delivery in 2005-2010
Grand Island Utilities	Grand Island	Kennecott Energy/PRB	C	430,000 t/y for 2 years	Delivery in 2005-2006
Menasha Utilities	Menasha	PRB	T	unspecified	Several-week test burn at 5-MW plant
Tennessee Valley Authority	System	Arch Coal/PRB	C	3 mt/y for 6 years	Delivery beginning in 2005
Texas Genco	Parish	PRB	So	Up to 2.7 mt for 1 year	Delivery in 2005
Wisconsin Electric Power Company	System	Colorado or PRB	So	750,000 t to 1 mt/y for 3 to 5 years	Delivery beginning in 2005
Xcel Energy	System	PRB	So	Up to 12 mt over 1 to 4 years	Delivery beginning in 2005

*Data obtained from: Coal Outlook, COAL Daily, U.S. Coal Review, FERC database, and personal contacts. Note: C = contract; mt = million short tons; mt/y = million short tons per year; PRB = Powder River Basin; So = solicitation; Sp = spot coal; t = short tons; t/y = short tons per year. *Wyoming State Geological Survey, Coal Section, April 2005.*

Coalbed Methane Update

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Coalbed methane (CBM) production reported by the Wyoming Oil and Gas Conservation Commission (WOGCC) for the first three quarters of 2004 was 249.7 billion cubic feet (BCF), with all but 2.8 BCF from the Powder River Basin (PRB) Coal Field. CBM production from the PRB is still declining after reaching a peak of 977 million cubic feet (MMCF) of gas per day in October 2003. The rate of production in September 2004 was only about 908.0 MMCF per day with indications that it will fall further during the remainder of 2004. Production for the first three quarters in the PRB was down 11.2 BCF, or 4.3% compared to the same period last year. Production from the rest of the state for three quarters of 2004 was up 1.2 BCF over the same period in 2003.

CBM production from the PRB is declining after peaking at 977 MMCF of gas per day in October 2003... and it will fall further in 2004.

Production

The WOGCC reported 13,276 producing and 4486 shut-in CBM wells across Wyoming in September 2004. Production of CBM in the PRB during the first nine months of 2004 was 246.9 BCF, down 4.3% from the same period in 2003 (**Table 19**). Statewide production of CBM for the first three quarters of 2004 averaged 27.7 BCF per month, which is down from 28.9 BCF for the same period in 2003 (**Tables 19** and **20**). CBM accounted for 17.4% of Wyoming's total natural gas production during the first nine months of 2004. CBM production from the PRB is declining after peaking at 977 MMCF of gas per day in October 2003; the rate of daily production in September 2004 was only about 908 MMCF and it will fall further in 2004.

Activities

The U.S. Bureau of Land Management (BLM) approved an exploratory CBM project proposed by Hudson Group in the Great Divide Basin about 45 miles north of Wamsutter. The BLM issued a finding of no significant impact (FONSI) for the project, which calls for 18 wells to be drilled in three phases of about six wells per year. The project will target coals in the Fort Union Formation in T26N, Rs96 to 97W (**location A, Figure 12**). Fort Union coal beds are also of interest in the Rock Springs uplift area (**Figure 18**).

The BLM issued a FONSI for the Pacific Rim exploration project proposed by Warren Exploration & Production. The project is located in Ts13 to 15N, Rs100 to 101W (**location B, Figure 12**) and will target sandstones and coals in the Almond Formation at depths ranging from 1500 to 5500 feet. Drilling is expected to last for two to four years, with a maximum of 120 wells. The life of the project is projected at 15 to 20 years. Warren has a large CBM leasehold in the Washakie Basin that consists of the Atlantic Rim project on the eastern rim of the basin, and the Pacific Rim project located on the western rim of the basin. Warren has identified over 1000 drilling locations between the two areas that encompass over 282,000 acres.

The BLM approved the Jolly Roger Pod Environmental Assessment (EA) proposed by Anadarko Petroleum and Warren Exploration & Production that includes parts of Ts18 to 19N, R90W (**location C, Figure 12**). The decision approves 16 new exploratory wells that will target Mesaverde Group coals and two additional water injection wells. The decision also approves new access roads, gas gathering pipelines, water gathering pipelines, and power lines. The project allows the two companies to determine if further development in the area is feasible.

The BLM issued a FONSI for a PRB project planned by Comet Energy Services. The Duck Creek Federal Coalbed Natural Gas project calls for drilling and completing 46 wells on federal lands, seven wells on fee lands, and one well on state land along with the associated gas production

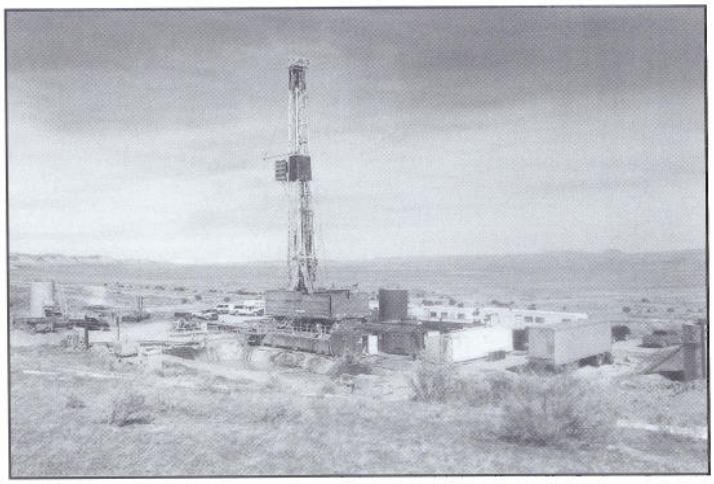

Figure 18. Wireline coring operations north of Rock Springs in Fort Union and Lance formation coal beds. Photograph by Nicholas R. Jones, March 2005.

and water disposal infrastructure for those wells. Comet's project will target upper and lower Pawnee coals in the Fort Union Formation at depths of 1800 to 2150 feet in parts of T38N, R72W (**location D, Figure 12**).

The BLM's Reservoir Management Group revised its procedures for review of potential drainage situations in the PRB coalbed methane play. According to the BLM, approximately $9.7 million in federal royalties were lost to drainage from June 2003 through May 2004. Under the revised process, letters will be sent to federal oil and gas leaseholders whose leases are adjacent to fee and state leases containing CBM wells. When cumulative CBM production from the non-federal wells reaches a level at which the potential for drainage exists, the federal lessee will be notified by the BLM. The regulations governing drainage are in CFR 3162.2-2 at: http://www.mt.blm.gov/oilgas/operation/ and outline the responsibility of the lessee to protect the federal mineral resource from drainage.

The BLM intends to prepare an EA to evaluate the continued implementation of the oil and gas leasing decisions in the 1985 Buffalo Resource Management Plan (RMP) as amended in 2003. The BLM will not offer oil and gas leases in coal-bearing areas (Fort Union Formation) during the preparation of this EA. This analysis will tie to the 1985 Buffalo RMP and may amend the current RMP. If the BLM determines that it will be unable to issue a FONSI, it will commence preparation of an EIS. The EA will consider options open to the BLM prior to lease issuance and will identify practices that should be applied to leases as stipulations. The options include closing an area to leasing or applying lease stipulations beyond the standard ones.

Table 19. Monthly Powder River Basin coalbed methane production in million cubic feet (MCF) (2000 through November 2004).

	2000		2001		2002		2003		2004	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	8,465,248	8,465,248	18,216,791	18,216,791	25,814,734	25,814,734	29,491,004	29,491,004	27,935,930	27,935,930
February	8,706,458	17,171,706	16,918,619	35,135,410	23,380,195	49,194,929	26,450,759	55,941,763	26,143,141	54,079,071
March	9,864,450	27,036,156	19,824,513	54,959,923	26,045,128	75,240,057	28,972,661	84,914,424	27,640,931	81,720,002
April	10,549,945	37,586,101	19,699,644	74,659,567	25,383,973	100,624,030	27,992,881	112,907,305	27,154,335	108,874,337
May	11,824,542	49,410,643	20,714,721	95,374,288	27,268,027	127,892,057	28,819,962	141,727,267	28,058,642	136,932,979
June	12,196,467	61,607,110	20,516,641	115,890,929	26,372,024	154,264,081	28,218,733	169,946,000	27,100,092	164,033,071
July	13,031,976	74,639,086	21,843,289	137,734,218	27,919,362	182,183,443	29,028,155	198,974,155	27,707,688	191,740,759
August	14,185,648	88,824,734	22,402,964	160,137,182	28,666,892	210,850,335	29,862,075	228,836,230	27,871,869	219,612,628
September	14,403,249	103,227,983	21,652,656	181,789,838	28,208,254	239,058,589	29,290,319	258,126,549	27,238,743	246,851,371
October	15,396,043	118,624,026	24,103,492	205,893,330	29,244,072	268,302,661	30,287,206	288,413,755	27,912,811	274,764,182
November	15,233,376	133,857,402	24,092,741	229,986,071	28,980,587	297,283,248	28,358,292	316,722,047	26,263,361	301,027,543
December	16,903,406	150,760,808	25,697,131	255,683,202	29,707,016	326,990,264	29,225,939	345,997,986		
Total		**150,760,808**		**255,683,202**		**326,990,264**		**345,997,986**		

Data from the Wyoming Oil and Gas Conservation Commission. MCF = thousands of cubic feet. *Wyoming State Geological Survey, April 2005.*

Table 20. Other Wyoming coalbed methane production in million cubic feet (MCF) (2000 through November 2004).

	2000		2001		2002		2003		2004	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	31	31	1,594	1,594	21,118	21,118	123,681	123,681	230,346	230,346
February	119	150	1,982	3,576	12,069	33,187	115,247	238,928	220,233	450,579
March	167	317	2,486	6,062	6,737	39,924	162,466	401,394	344,691	795,270
April	366	683	2,738	8,800	6,713	46,637	157,434	558,828	302,059	1,097,329
May	637	1,320	4,255	13,055	8,640	55,277	179,883	738,711	331,435	1,428,764
Jun	1,494	2,814	5,149	18,204	32,691	87,968	177,829	916,540	371,031	1,799,795
July	992	3,806	5,453	23,657	39,716	127,684	213,937	1,130,477	380,131	2,179,926
August	1,417	5,223	3,329	26,986	52,391	180,075	214,106	1,344,583	333,907	2,513,833
September	1,459	6,682	2,993	29,979	69,082	249,157	220,629	1,565,212	312,447	2,826,280
October	1,165	7,847	2,667	32,646	71,672	320,829	221,578	1,786,790	313,674	3,139,954
November	1,335	9,182	4,434	37,080	77,640	398,469	186,793	1,973,583	314,994	3,454,948
December	1,317	10,499	39,232	76,312	99,629	498,098	203,161	2,176,744		
Total		**10,499**		**76,312**		**498,098**		**2,176,744**		

Data from the Wyoming Oil and Gas Conservation Commission. MCF = thousands of cubic feet. *Wyoming State Geological Survey, April 2005.*

Industrial Minerals and Uranium Update

Ray E. Harris, Wyoming PG-46

Senior Staff Geologist–Industrial Minerals and Uranium, Wyoming State Geological Survey

Production of the major industrial minerals in Wyoming continued steady through three quarters of 2004. Production of trona, the most valuable industrial mineral commodity, decreased from 2003; our earlier forecast will be almost a million tons too high by the end of 2004. Uranium production continued at two *in situ* localities in Wyoming but total production for the year is expected to be less that the total for 2003. The price of yellowcake increased from $14.50 per pound at the end of 2003 to $20.25 through September, 2004. Inquiries to the Industrial Minerals and Uranium (IM&U) Section of the Wyoming State Geological Survey (WSGS) regarding reopening closed uranium mines or locating new deposits continued to increase during the first three quarters of 2004.

Decorative stone is in a slump nationwide because of low prices for imported products; dimensional stone is now quarried from only one Wyoming locality. The gypsum plant at Cody was purchased by British Paper Board; the plant now operates under the name BPB Celotex. Bentonite production for 2004 should exceed that in 2003.

Bentonite

Wyoming is the nation's leading producer of sodium bentonite, a clay mineral. About 25% of the bentonite produced is used in pet waste absorbent (kitty litter), 20% is used in drilling mud, 19% is used as a foundry sand bonding agent, 13% is used as a binder in iron ore pelletizing, and 23% in other uses (Virta, 2005). Bentonite is mined in Wyoming at numerous pits and blended, dried, and packaged in 13 nearby mills operated by seven companies (**Figure 19**). Bentonite production is increasing, and production in 2004 should exceed the 3.8 million short tons mined in 2003 (Stauffenberg, 2004).

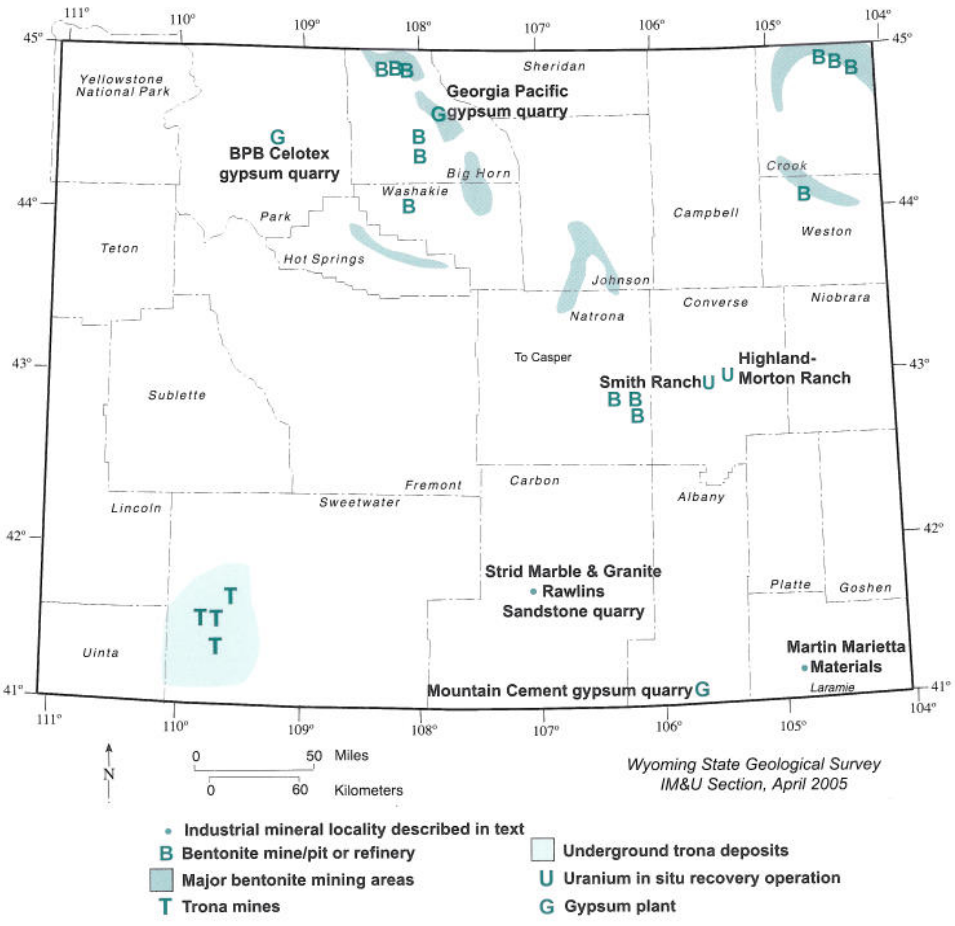

Figure 19. Index map of Wyoming showing the location of industrial mineral and uranium sites and selected mining areas mentioned in the text. Locations are approximate and may represent more than one site.

Construction aggregate

Construction aggregate is the crushed and sized rock or sized sand and gravel used primarily mixed with cement or asphalt to produce concrete or asphaltic paving, as a fill material in construction, and as other roadbed and gravel surfacing material. Construction aggregate is produced in all of Wyoming's 23 counties, though some sources are not active every year. Crushed stone, including granite, gneiss, marble, limestone, dolomite, and clinker (scoria) is produced in Wyoming. The state's largest crushed stone producer is Martin Marietta Materials, which produces crushed and sized granite (geologically a quartzofeldspathic gneiss) from their quarry at Granite Cañon, west of Cheyenne (**Figures 19** and **20**). Producers of sand and gravel account for significant production (**Figure 21**), although these operations tend to be smaller and serve local sales areas. Since the price of aggregate at the point of use includes mostly transportation costs, these sources are located as close to the primary end use as possible.

Dimensional and decorative stone

Dimensional sandstone was quarried south of Rawlins in 2004 and split by Strid Marble and Granite of Cheyenne to produce split-face stone for an addition to the Albany County Courthouse in Laramie (**Figure 22**). This is currently the only dimensional stone quarried in Wyoming, although Strid and other stone processors continue to fabricate dimensional stone from quarries outside of Wyoming. A decorative travertine that was test quarried on the Wind River Indian Reservation a couple of years ago is being displayed as a polished stone known as "cookies and cream."

The decorative stone industry in the U.S. is in a slump due to the low prices of decorative stone imports. For example, the stone called "Ubatuba" from Brazil is on the U.S. market at $4.00 per square foot for a polished slab. A slab measures approximately 5 feet x 10 feet x ¾ inch. A deposit of an almost identical stone is found in Wyoming (Harris, 2003). Even without quarrying costs, the cost for cutting a quarried block into slab and polishing it into the finished product in the U.S. is $7.50 per square foot. Adding quarrying costs, transportation costs, and a profit margin will raise the price of domestically produced slab to around $18.00 per square foot which is certainly not competitive with imported slab.

Stone interest in Wyoming is currently limited to flagstone, fieldstone (rough stone), and thin cut veneer for local and nearby markets. These low-cost materials can be produced competitively with imports since transportation costs contribute the most to the final product cost.

Gypsum

Gypsum is mined in Wyoming at three localities (**Figure 19**), two in the Bighorn Basin for wallboard production at mine mouth plants, and one near Laramie where it is mined intermittently by Mountain Cement for use as a retardant in cement manufacture. The major crude gypsum-producing states were Nevada, Oklahoma, Iowa, Texas, California, Arkansas, and Indiana, which together accounted for 78% of the total mined gypsum in 2004. Almost 95% of domestic consumption was used to manufacture wallboard, cement, and plaster products used by the construction industry. One million short tons of gypsum was used for agricultural applications in the U.S.; small amounts of high-purity gypsum were used in a wide range of industrial processes, such as

Figure 20 (left). Granite Cañon crushed stone aggregate quarry west of Cheyenne, January 2005. Each bench is approximately 30 feet high.

Figure 21 (right). Sand and gravel operation northeast of Wheatland, Wyoming, operated by Alexander Construction of Wheatland in February 2005. Laramie Peak is the mountain in the background.

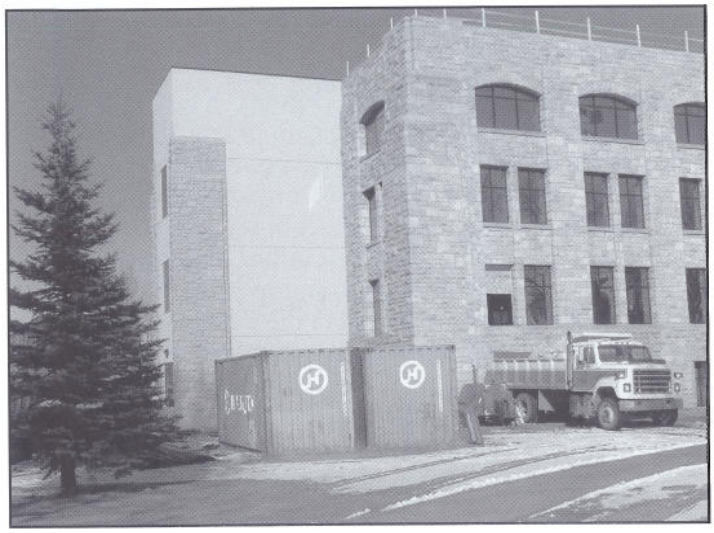

Figure 22. Addition to Albany County Courthouse (left side of photo) partly faced with stone quarried near Rawlins. The original courthouse building (right) is faced with stone identical to many buildings on the University of Wyoming campus.

smelting and glassmaking, which accounted for the remaining uses (Founie, 2005).

Domestic resources of gypsum are adequate but unevenly distributed. For wallboard manufacturing, imports from Canada are substituted for domestic supplies in the U.S. in regions where there are no significant gypsum deposits such as the Northeast and the Pacific Northwest. Imports from Mexico augment domestic gypsum supplies for wallboard manufacturing along parts of the western U.S. seaboard. Large gypsum deposits occur in the Great Lakes region, Midcontinent region, and several Western states (Founie, 2005), including Wyoming. Wyoming is strategically placed to supply gypsum and gypsum products to the Pacific Northwest. Interest in additional gypsum production from Wyoming remains high.

Trona

Four companies in Wyoming operate four plants with associated underground trona mines (**Figure 19**). A fifth Wyoming plant and mine, FMC Granger, is inactive. A company in California operates one plant, with the trona mined from a surface evaporite lake. These five active U.S. producers have a combined annual capacity to produce 14.5 million short tons of soda ash.

One company in Wyoming (Solvay Minerals) owns an inactive soda ash plant in Colorado. This plant originally produced soda ash from nahcolite ($NaHCO_3$) mined *in situ*. Since nahcolite production ceased, the operator had been producing soda ash from trona mined in Wyoming, but the plant closed in August 2004.

Most of the trona, sodium sesquicarbonate ($Na_2CO_3 \bullet NaHCO_3 \bullet 2H_2O$), is used to make soda ash (sodium carbonate). The total value of domestic soda ash produced in the U.S. in 2004 was estimated to be about $820 million. Coproducts produced in Wyoming from mined trona include sodium sulfite and caustic soda. According to the U.S. Geological Survey, the estimated 2004 distribution of soda ash by end use was glass, 49%; sodium chemicals, 28%; soap and detergents, 11%; distributors, 4%; miscellaneous uses, 3%; flue gas desulfurization, 2%; pulp and paper, 2%; and water treatment, 1%. (Kostick, 2005).

The reported price of soda ash has remained constant over the past five years at $115.74 per short ton. Approximately 2.8 million short tons of soda ash capacity is mothballed in the U.S. The industry announced price increases of $22 per short ton in the third quarter of 2004 to offset higher energy and transportation costs (Kostick, 2005).

The U.S. had been the world's leader in soda ash production for nearly 100 years until China, a producer of synthetic soda ash, produced more than the U.S. in 2003. China is expected to produce 13.2 million short tons of soda ash in 2004, exceeding the U.S. total of 11.9 million short tons. The overall world demand for soda ash is expected to grow from 1.5 to 2% annually in the short term. U.S. demand may be slightly higher in 2005 (Kostick, 2005).

The State of Wyoming's Consensus Revenue Estimating Group (CREG), using WSGS estimates, projects the amount of trona mined in Wyoming in 2004 to be 17.1million short tons, which includes trona produced from mine water. This figure is down slightly from 2003 (**Table 1**). The amount of mined trona estimated for 2005 is 17.0 million short tons, reflecting a small decrease. The price of mined trona is expected to remain constant at $35.50 per short ton (**Table 2**) according to CREG. This is $2.00 per short ton less than our forecasts made in October 2003.

Uranium

The spot market price of yellowcake (oxidized uranium—the product of Wyoming's uranium mills) jumped during the first half of 2004 from $14.50 per pound of yellowcake to $18.50 per pound, and by the end of the third quarter had reached $20.00 per pound, according to the Ux Consulting Company, LLC., The Uranium Exchange Company (http://www.uxc.com/review/uxc_prices.html) (**Figure 23**) and the Rocky Mountain Minerals Scout. Prices continued to climb

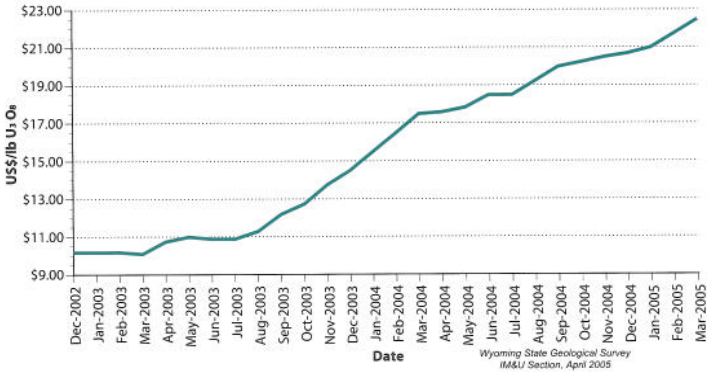

Figure 23. Uranium spot market prices, end of December 2002 through March 2005.

in late 2004 and into early 2005. Yellowcake is uranium oxide with a varying amount of other elements, having no definite chemical formula. The price increase is probably due in part to an anticipated decrease in the amount of uranium from Russia, which had been manufactured from weapons-grade uranium diluted to power plant fuel.

The price increase triggered a return of the State's severance tax on uranium production. A spot market price of $14.00 per pound or less was legislatively exempt from severance tax. When the spot market price exceeded this figure, the Wyoming Department of Revenue began collecting severance tax from the producer in June 2004.

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 19**). CAMECO, of Saskatoon, Saskatchewan, also owns the only other current uranium production in the U.S. at Crow Butte, Nebraska. The Smith Ranch and Highland/Morton Ranch operations are considered as one operation.

According to CREG, uranium production from the two Wyoming mines in 2003 was 1.2 million pounds of yellowcake, and production in 2004 should continue at 1.2 million pounds. CREG projects production will increase by 0.3, 0.4, and 0.6 million pounds in 2005, 2006, and 2007 respectively, leveling off at 2.5 million pounds in 2008 and 2009 (**Table 1**).

Increased uranium prices resulted in the opening of some small underground uranium mines in the Colorado Plateau area of western Colorado and eastern Utah. This area was the location of the first uranium production in the U.S. beginning in the early 1950s. Small amounts of uranium ore from this area around Naturita, Colorado, were shipped in late 2004 to the Cotter Corporation mill at Cañon City, Colorado. This mill has the capability to extract uranium from ore and produce yellowcake. No production figures are currently available, but the production is small compared to Wyoming and Nebraska. No small mines have reopened in Wyoming so far.

According to an article by Dorothy Kosich posted on the Internet site www.mineweb.com in late 2004, uranium industry executives are predicting a growth in exploration, production, and an increase in the price of yellowcake. This includes an increase in the number of nuclear power plants worldwide, increasing world uranium requirements over 200% by 2019, and projecting uranium prices to increase to around $30.00 per pound. Most of the increased production is expected to come from Canada and Australia. However, other producing countries, including the U.S., could see production increases.

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Metals and Precious Stones Update

W. Dan Hausel, Wyoming PG-1025

Senior Economic Geologist–Metals and Precious Stones, Wyoming State Geological Survey

The Metals and Precious Stones Section of the Wyoming State Geological Survey (WSGS) continued working on several projects including proposals to search the State Line district and the Leucite Hills for undiscovered diamond deposits. Diamond indicator minerals have been recovered from the Bighorn Basin, and area heretofore unexplored for diamonds. Investigations related to gold at South Pass, and colored gemstones in the Laramie Mountains and Wind River Range were also conducted by the section. The section investigated a large opal deposit at Cedar Rim (near Beaver Divide, south of Riverton) and prepared an open file report that described some of the largest opals in North America.

Exploration activities

Currently, the Metals and Precious Stones Section is seeking support to search for hidden olivine lamproites in the Leucite Hills by using traditional stream sediment sampling methods, aerial photography, and airborne magnetics and electromagnetics. Preliminary studies have shown the presence of diamond-stability chromites in two lamproites on the northeastern edge of the Leucite Hills volcanic field of southwestern Wyoming.

The WSGS received samples from two prospectors who had recovered pyrope garnets (diamond-indicator miner-

als) from anthills and sediments in the Bighorn Basin near Thermopolis and farther west. This basin remains unexplored for diamonds and represents another of the several hundred diamond-indicator anomalies identified to date in Wyoming. The enormous number of kimberlitic indicator mineral anomalies in the state support the fact that Wyoming has been intruded numerous times by swarms of mantle-derived intrusives, some of which are diamondiferous.

Over the past 28 years, the Section has identified several interesting mineral occurrences and deposits in Wyoming and made a discovery of a previously overlooked gold district in the Rattlesnake Hills west of Casper. Other gold anomalies were discovered in the Seminoe Mountains, South Pass, Medicine Bow Mountains, and Sierra Madre. The Section also discovered a completely overlooked ultramafic massif in the Sierra Madre, Puzzler Hill, that yielded significant palladium, nickel, gold, platinum, copper, and silver anomalies and also found some diamond deposits in the Laramie Mountains and a variety of other gemstones around the state including rubies, sapphires, peridot, pyrope garnet (cape rubies), chromian diopside, chromian enstatite, heliodor, opal, aquamarine, kyanite, and iolite (water sapphire).

About eight years ago, the Section discovered a multi-gem deposit in the Laramie Mountains west of Wheatland. Known as the Palmer Canyon deposit, it contains gem-quality sapphire, ruby, kyanite, and a beautiful gem known as iolite. Iolite is sometimes referred to as water sapphire, and is primarily mined in Sri Lanka; large gemstones are rare. This attractive gemstone appears similar to sapphire and amethyst, but tends to change color as it is rotated in light from a dark purplish blue, to light blue, to light gray. At the time of the discovery, the WSGS recovered some fabulous gem material including one of the largest iolite gems in the world. This stone, referred to as the Palmer Canyon Star, weighs 1750 carats (**Figure 24**).

Last field season (2004), Hausel and Sutherland investigated a second iolite occurrence south of Palmer Canyon near Grizzly Creek. This deposit contains some extraordinary specimens. One iolite gem recovered by Hausel is believed to be the largest in the world (**Figure 25**). The stone weighed an incredible 10.65 pounds or 24,150 carats! However, much larger gems were identified by the two geologists during reconnaissance, but these will require special tools to recover (**Figure 26**). If properly sampled, some specimens estimated to weigh more than 100,000 carats will probably be recovered. The WSGS also indicates that the geology in this area is very favorable for the discovery of additional iolite, ruby, and sapphire deposits.

In addition to iolite, during the last field season Hausel and Sutherland investigated a large opal deposit at Cedar Rim in the western Granite Mountains south of Riverton. This may be one of the larger deposits in North America. The geologists sampled opal from portions of 14 sections and recovered some of the largest opals in North America. Three

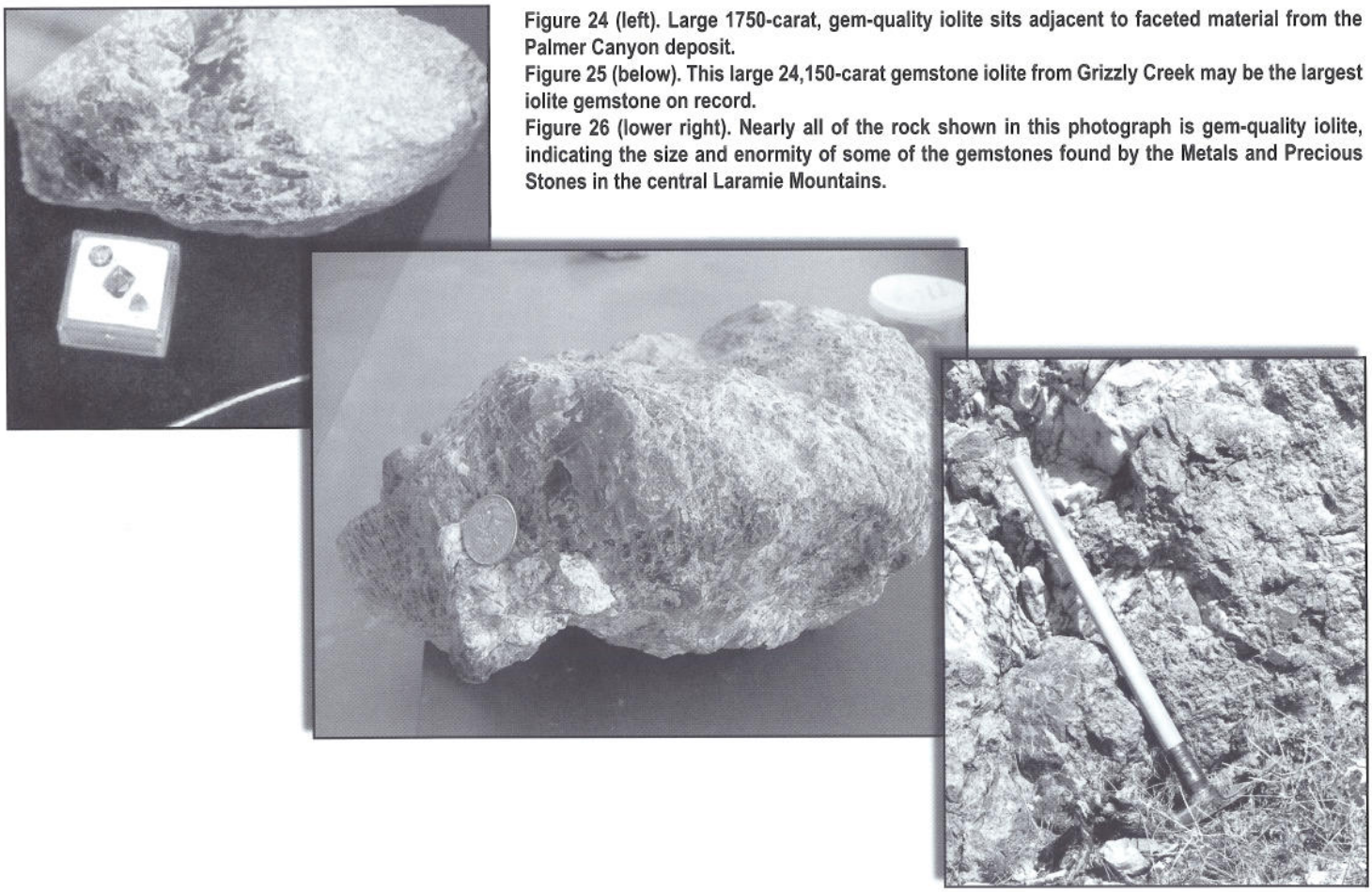

Figure 24 (left). Large 1750-carat, gem-quality iolite sits adjacent to faceted material from the Palmer Canyon deposit.
Figure 25 (below). This large 24,150-carat gemstone iolite from Grizzly Creek may be the largest iolite gemstone on record.
Figure 26 (lower right). Nearly all of the rock shown in this photograph is gem-quality iolite, indicating the size and enormity of some of the gemstones found by the Metals and Precious Stones in the central Laramie Mountains.

giant opals collected by the WSGS weighed 25,850 carats (11.4 pounds), 57,100 carats (25.18 pounds) and 77,100 carats (34 pounds), respectively!

Manuscripts submitted for publication

(1) Bulletin on Minerals and rocks of Wyoming—A guide for collectors, prospectors, rock hounds, and the layman, by W. Dan Hausel. In preparation.

(2) A Report of Investigations on Geology and Geochemistry of the Leucite Hills Volcanic Field, Rock Springs Uplift, Greater Green River Basin, Southwestern Wyoming (includes geologic map and a summary of exploration methods for lamproite), by W. Dan Hausel. In preparation.

(3) Geologic map of the Saratoga 1:100,000-scale Quadrangle, by Wayne M. Sutherland and W. Dan Hausel. Currently available as WSGS Open File Report 04-10; digital version for publication in the WSGS Map Series in preparation.

(4) Geology of the Cedar Rim opal deposit, Granite Mountains, central Wyoming, by W. Dan Hausel and Wayne M. Sutherland. Published as WSGS Open File Report 05-1.

(5) Diamond deposits: SME's Industrial Minerals and Geology, by W. Dan Hausel.

(6) Geology of gemstones and precious metals in Wyoming, by W. Dan Hausel. Wyoming Geological Association (WGA) 2005 field conference (abstract).

Manuscripts in progress

(1) Gemstones of the World: Geology and occurrence, by W. Dan Hausel. This is an extensive book scheduled to be published by the Society of Exploration, Mining and Metallurgy of SME in 2006.

(2) Diamond deposits in the Wyoming craton: Characteristics, geology, exploration, and testing, by W. Dan Hausel. WSGS memoir.

(3) 1:1,000,000-scale mineral district map of Wyoming, by W. Dan Hausel.

(4) 1:100,000-scale geologic map of the South Pass Quadrangle, by Wayne M. Sutherland and W. Dan Hausel. WSGS Open File Report.

(5) Additional WSGS memoirs in the planning stages on colored gemstones, precious metals, and base metals.

Special recognition

On Friday, October 22, 2004, the WGA honored W. Dan Hausel, Senior Economic Geologist of the WSGS with the Association's 2004 Distinguished Service Award for grateful recognition and outstanding endeavors and contributions to the work and progress of the Association. The award was presented at the Casper Petroleum Club, and is awarded once every few years to an individual who has made extraordinary contributions to Wyoming's geology and the advancement of the Association.

The award, presented by Ralph Specht, Vice President of the WGA, was followed by a standing ovation acknowledging Hausel's contributions. Mr. Specht read the following to the membership:

W. Dan Hausel received BS and MS degrees in Geology from the University of Utah in 1972 and 1974. Since 1975, he has worked as a consultant for various companies and as a research geologist for the Wyoming State Geological Survey. Currently, he occupies the position of Senior Economic Geologist for the WSGS where his duties include investigations related to precious and base metals, gemstones, mineralogy, mining districts, Archean greenstone belts and diamondiferous host rocks.

During the past 27 years, he mapped more than 600 square miles of historic mining districts and Precambrian geology including the two largest kimberlite districts in the US and the largest lamproite field in North America. His work has resulted in the discovery of some diamond, several colored gemstone occurrences and several base and precious metal occurrences and deposits, as well as a previously unrecognized gold district in Wyoming (Rattlesnake Hills). While on leave from the state, he has consulted on several diamond and gold projects around North America, and provided the initial mapping on the Donlin Creek gold deposit in southwestern Alaska, which is now considered to be the largest undeveloped gold deposit in North America.

He has authored or co-authored more than 450 books, professional papers, general interest articles and geological maps, and lectured to hundreds of groups around North America. In 1992, he was awarded the American Association of Petroleum Geologist's Energy Mineral's Division President's Award and the Wyoming Geological Association's Certificate of Appreciation for Outstanding Endeavors and Contributions. In 1994, he was a Distinguished Lecturer for the Laramie Lyceum; in 1998, was listed as a Distinguished Lecturer of the University of Wyoming Department of Geology and Geophysics, and was also presented the Prospector's Best Friend Award by the Rocky Mountain Prospectors and Treasure Hunters. In 2001, he was presented the Education Award and elected to the National Rock Hound and Lapidary Hall of Fame for his contributions to the education of rock hounds and amateur mineralogists and in 2003, he was elected to the Colorado Chapter of the International Order of Ragged Ass Miners. His achievements have been highlighted in several Who's Who documents including Who's Who in Science & Engineering, Who's Who in the West, Who's Who in America, Who's Who in the World, 2,000 Notable American Men, and 5,000 Personalities of the World.

His hobbies include sketching and martial arts. His artwork appears in publications, galleries, and on book covers. He is considered one of the top martial arts instructors in North America – holds the highest possible

black belt rank in karate (10th degree black belt) has been inducted into 7 Halls of Fame for contributions to the martial arts and has been recognized as the "International Grandmaster of the Year," "Grandmaster of the Year," and "International Instructor of the Year."

The presentation was followed by a lecture by Hausel on the Geology of gemstone deposits which included discussions on some more gemstone discoveries made by the WSGS in the state.

Over the years, Hausel and the Metals and Precious Stones Section has presented almost 400 talks to various groups around the country as well as 35 talks to the WGA in Casper. The Section has also mapped nearly every hard-rock mining district in the state including South Pass, Atlantic City, Miners Delight, Lewiston, Seminoe Mountains, Rattlesnake Hills, Copper Mountain, Cooper Hill, Silver Crown, State Line, Iron Mountain, Keystone, and the Encampment district.

Rock Hound's Corner: Andalusite, Kyanite, Sillimanite, and Staurolite

W. Dan Hausel, Wyoming PG-1025

Senior Economic Geologist–Metals and Precious Stones, Wyoming State Geological Survey

Andalusite, cordierite, kyanite, sillimanite, and staurolite are all alumino-silicates associated with alumina-rich, mica schists known as metapelites. Usually, one or more of these alumino-silicates are found in the same metamorphic terrane and can provide a general barometer of the intense pressure and temperature that the mica schist was subjected to. For example, kyanite forms at relatively high pressure and low temperature compared to sillimanite and andalusite. Andalusite (as well as cordierite) will form at relatively higher temperatures and lower pressures than sillimanite and kyanite. Sillimanite forms at high pressures and temperatures between the other alumino-silicates.

Andalusite, kyanite, and sillimanite are polymorphs with the general chemical composition of $Al_2(SiO_5)$. *Andalusite* is orthorhombic and forms dull, rough, prismatic crystals with square cross sections in mica schists, and is often partially replaced by sericite (a fine-grained white mica). Most andalusite found in Wyoming is opaque, gray to brown. However, andalusite crystals of brownish pink, white, rose-red, red-brown, green, yellow, and violet have been reported elsewhere. It has a hardness of 6.5 to 7.5 (Mohs scale) and specific gravity of 3.1 to 3.2. Because of the common partial replacement of andalusite by sericite, the specific gravity may be relatively low. Its hardness is often difficult to determine because of partial replacement by softer mica.

Kyanite is the triclinic polymorph of andalusite and sillimanite. Typically, kyanite forms distinct light-blue, bladed, opaque crystals with a specific gravity of 3.53 to 3.65 (**Figure 27**). Gem varieties of kyanite are uncommon but are found in relative abundance in the central Laramie Mountains of Wyoming.. Good crystals of kyanite have a unique hardness which is useful in identifying this mineral. Parallel to the greatest length of the crystal [(c-axis) or m(001)], it has a hardness of 5 and can be scratched with a pocket knife. However, in the direction of the short axis, it has a hardness of 7 and can not be scratched with a pocket knife unless the mineral is altered or weathered. In other words, there should be a noticeable difference in the mineral's hardness depending on the direction it is scratched. This, along with its distinctive blue color, are useful in identifying this mineral.

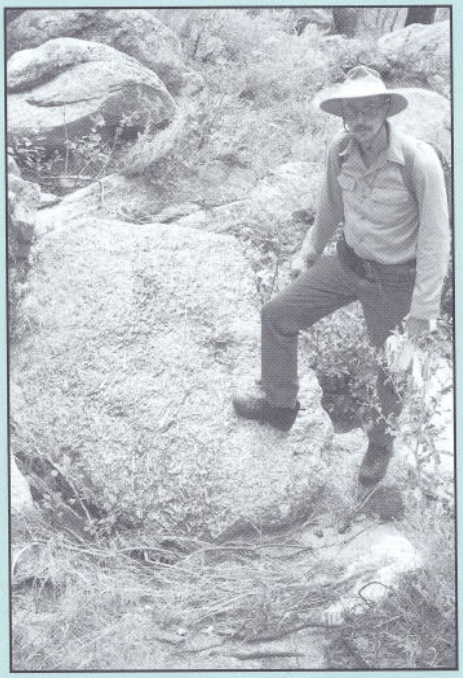

Figure 27. Outcrop of kyanite schist at Grizzly Creek, Laramie Mountains. The distinct prismatic crystals in the rock are kyanite; many are gem quality.

Sillimanite, another orthorhombic polymorph, forms slender, prismatic, or fibrous white, colorless, to very light green crystals with vitreous to silky luster. Sillimanite has a hardness of 6.5 to 7.5 and specific gravity of 3.23 to 3.27. The mineral rarely forms transparent crystals suitable for cutting. No gem varieties of sillimanite have yet been reported in Wyoming.

Staurolite, a complex alumino-silicate (Fe,Mg)2(Al,Fe)9O6(SiO4)4(O,OH)2, is a monoclinic (pseudo-orthorhombic) mineral with a hardness from 7 to 7.5. It commonly forms distinct brown to yellow-brown, cruciform (cross-like) twins, although it may occur as flat, elongated crystals. It is typically associated with kyanite, muscovite, and almandine garnet. No gem varieties of staurolite are known in Wyoming.

These metamorphic minerals are restricted to the Precambrian cores of several Wyoming mountain ranges where large regions of moderate to relatively high-grade metamorphic

rocks were deeply buried during the geological past. The lithostatic pressure from a thick pile of sedimentary rocks that once buried these terranes resulted in metasomatic alteration of the rocks. In other words, the original minerals in these rocks slowly changed (metamorphosed) to other minerals more suited to withstand the higher pressure and temperature.

In particular, many alumina-rich sedimentary rocks (such as shales) were greatly affected by this metamorphism. Under the pile of sedimentary rocks, these alumina-rich rocks slowly changed to mica-schists with a distinct schistose fabric. In addition to mica, many of these schists also grew porphyroblasts (large metamorphic crystals) with aluminum-rich silicate minerals known simply as alumino-silicates. Much later in geologic time, dramatic forces in the earth uplifted large blocks of the earth many miles along faults, and produced today's mountain ranges. Erosion removed much of the overburden so that today we see the old, metamorphic crystalline cores exposed in the mountain ranges. If you examine the Geologic Map of Wyoming (see Love and Christiansen, 1985), you will note that the only place that you see these ancient Precambrian rocks are in the cores of many mountain ranges. Also note that wherever you see metasedimentary rocks on the map, it indicates some of the best places to search for the alumino-silicates.

In some of these metasedimentary areas, you might find some attractive specimens of mica schist with abundant sky-blue kyanite crystals. Rocks that have been called peanut schists, which contain porphyroblasts of andalusite and cordierite, are found in the South Pass area of the Wind River Mountains; staurolite crosses in mica schists and some gem-quality, sapphire-blue crystals of cordierite have been found west of Wheatland. Other areas in Wyoming where the alumino-silicates have been reported include Copper Mountain in the Owl Creek Mountains, South Pass in the Wind River Range, the Seminoe Mountains, Elmers Rock greenstone belt in the Laramie Mountains, and the Sierra Madre. See Hausel and Sutherland (2000) for a detailed description of these areas.

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GEOLOGIC MAPPING, ACTIVITIES, AND PUBLICATIONS UPDATE

Geologic Mapping, Paleontology, and Stratigraphy Update

Alan J. Ver Ploeg, Wyoming PG-1587

Senior Staff Geologist–Geologic Mapping, Wyoming State Geological Survey

The Wyoming State Geological Survey (WSGS) submitted a mapping project proposal for STATEMAP 2005 to the U. S. Geological Survey (USGS) in November 2004. The proposal consisted of four subprojects: 1) mapping and compiling the Midwest and Bill 1:100,000-scale quadrangles; 2) digitizing four 1:24,000-scale maps and four 1:100,000-scale maps (two bedrock and two surficial maps); 3) mapping and compiling the Sundance 1:100,000-scale Quadrangle; and 4) mapping and compiling the Lusk 1:100,000-scale Quadrangle. The WSGS recently learned that three of the four subprojects would be funded totaling $94,804.

The Casper College Tate Museum announced the theme and dates for their annual field conference in Casper. The conference theme is: "The Cretaceous-Paleocene K-T boundary: Adaptive radiation after the bottleneck" and it will take place on June 3, 4, and 5, 2005.

Two new articles relating to Wyoming geology and stratigraphy were recently released. The articles discuss: 1) a new geographic information system (GIS) technique for remote surface mapping using orthophotos and geologic maps draped over digital elevation models and 2) factors controlling gas production from low-permeability sandstone reservoirs in the Greater Green River basin.

STATEMAP 2005

Staff members of the WSGS proposed and submitted a mapping project for the USGS's STATEMAP 2005 Program in November 2004. The proposed mapping project consisted of four subprojects: 1) map and compile the Midwest and Bill 1:100,000-scale quadrangles; 2) digitize bedrock geologic maps of the South Pass and Newcastle 1:100,000-scale quadrangles and the Guernsey, Guernsey Reservoir, Miners Delight, and Pilot Hill 1:24,000-scale quadrangles, and digitize the surficial geologic maps of the Baggs and Medicine Bow 1:100,000-scale quadrangles; 3) map and compile the Sundance 1:100,000-scale Quadrangle; and 4) map and

compile the Lusk 1:100,000-scale Quadrangle. These four subprojects are listed in order of priority. Current mapping priorities established by the WSGS in cooperation with Wyoming Geologic Mapping Advisory Committee include: 1) producing geologic maps to support coalbed methane (CBM) exploration/production activities and associated ground and surface water protection needs in the Powder River Basin and other basins with CBM activity, 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 energy/mineral exploration and development.

The Mapping Section of the WSGS proposed mapping and compiling the bedrock geology for the Midwest and Bill 1:100,000-scale quadrangles, with funding from STATEMAP 2005. Completion of these maps is needed to augment expansion to the south of the recently completed Northern Powder River Basin geologic, hydrologic, and water quality database project, as well as to complete all the 1:100,000-scale mapping for the northeastern quadrant of the state. Regarding the Midwest map, efforts will concentrate on compiling the numerous existing maps to the 1:100,000 scale, incorporating some unpublished work in the northern section of the map, and edge matching the geology with the Kaycee Quadrangle to the north and the Casper Quadrangle to the south. For the Bill Quadrangle, work will entail compiling existing mapping at 1:100,000 scale, filling in any gaps in existing mapping, and edge matching with the bordering Reno Junction and Midwest quadrangles.

The Midwest Quadrangle is located in the central part of Wyoming (**Figure 28**). The quadrangle includes bedrock ranging in age from Pennsylvanian to Paleocene. The dominant structural features included in the map area are a portion of the Casper arch and the Salt Creek/Teapot anticlinal complex, with their associated structures. The northwestern part of the map includes folds and faults that make up the southern end of the Bighorn uplift. The axis of the Powder River Basin (PRB) runs northwest to southeast, approximately 10 to 15 miles east of the quadrangle.

The Bill Quadrangle is immediately east of the Midwest Quadrangle and is located in the southern PRB (**Figure 28**). The quadrangle includes bedrock ranging in age from Late Cretaceous to Eocene. The axis of the PRB runs northwest to southeast, on the west side of the quadrangle.

The Mapping Section will complete the unmapped parts of the quadrangles and review and evaluate the compiled parts of the maps. Preliminary digital geologic maps will be prepared for comment and review, with final versions published as color geologic maps (proposed for STATEMAP 2006). Funding from STATEMAP 2005 will be used to acquire

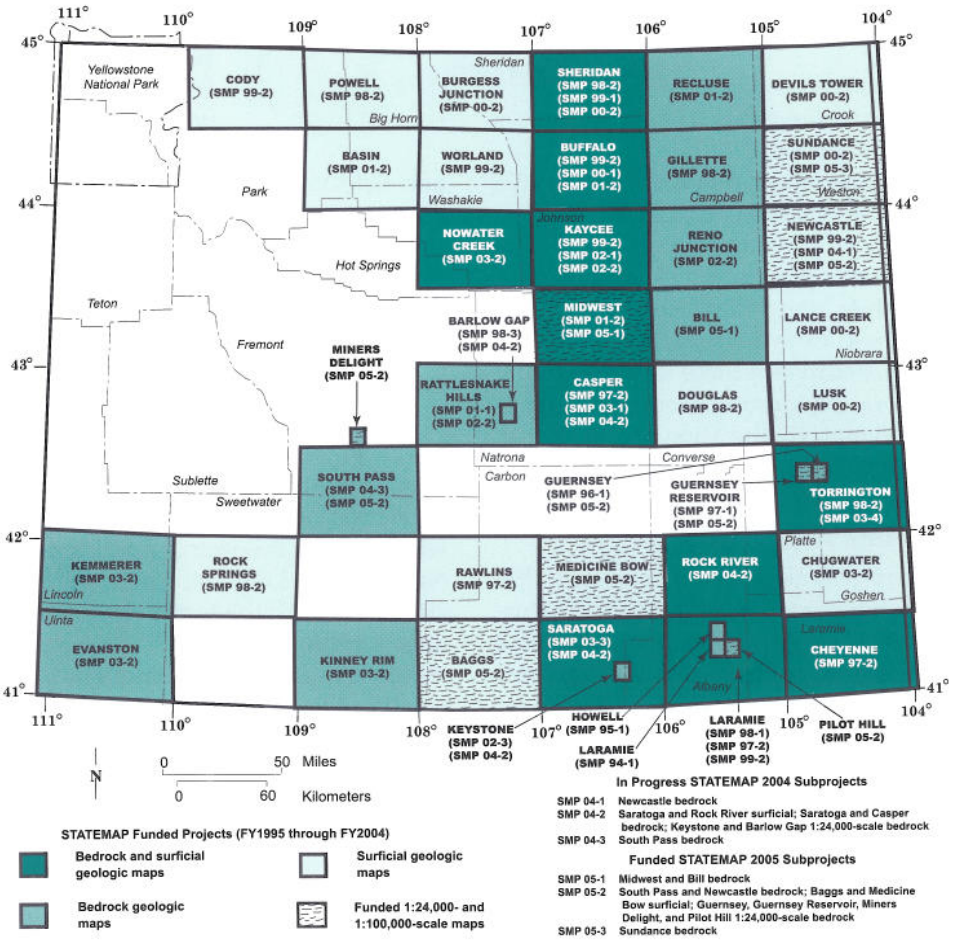

Figure 28. Index to funded, in-progress, and completed STATEMAP projects in Wyoming.

any needed aerial photography, negatives, and orthophoto sheets for the 1:24,000/1:100,000-scale bases, for the salary of one geological assistant and a GIS technician to assist with digitizing efforts, and for field vehicle rental and travel expenses.

The GIS Section of the WSGS proposed digitizing the South Pass and Newcastle 1:100,000-scale and the Guernsey, Guernsey Reservoir, Miners Delight, and Pilot Hill 1:24,000-scale bedrock geologic quadrangle maps. The Baggs and Medicine Bow 1:100,000-scale surficial geologic quadrangle maps (**Figure 28**) will be digitized. The six bedrock maps are currently being prepared or available as published paper maps from the WSGS. The two surficial geologic maps are currently available as unpublished paper maps completed by the Geologic Hazards Section of the WSGS. For each map, the geology layer will be scanned, converted from a raster image to a vector image, and edited to be consistent with National Digital Mapping Standards. Digital topography and public land survey data exist for each map and will be acquired from the USGS EROS Data Center. Each map falls under one or more of the three mapping priorities listed above. STATEMAP 2005 funding will be used to acquire existing 1:100,000-scale digital topographic and public land survey data from EROS Data Center, for salary for GIS assistants, and map scanning costs.

The Tate Museum is celebrating its 25th anniversary this year and area geologists, paleontologists, and Museum supporters are urged to join this celebration.

The Metals and Precious Stones Section of the WSGS proposed mapping and compiling the bedrock geology for the Sundance 1:100,000-scale Quadrangle (**Figure 28**). This area includes the southern part of the Bear Lodge Mountains, Black Buttes, and Mineral Hill alkalic complexes. These areas are of potential economic interest for gold, rare earth elements, fluorite, tin, copper, and other base metals. The geologic environment in these areas is similar to the Cripple Creek District of Colorado. Because of these similarities, the region is of interest to several exploration groups. Two companies have recently staked much of the Mineral Hill district for gold and silver, at least two companies have interests in the Bear Lodge Mountains for gold, and several prospectors have shown interest in Sand Creek for placer gold.

Completion of this map will augment expansion to the east of the Northern Powder River Basin geologic, hydrologic, and water quality database project, as well as helping complete the 1:100,000-scale mapping for the northeastern quadrant of Wyoming. In addition, the map will support mineral exploration and production. Completion of this quadrangle addresses two of the three stated mapping priorities. Funding from STATEMAP 2005 will be used to acquire any needed aerial photography, negatives, and orthophoto sheets for the 1:100,000-scale bases, to pay the salary of one geological assistant, and for field vehicle rental and travel expenses.

The Industrial Minerals and Uranium Section of the WSGS proposed mapping and compiling the bedrock geology for the Lusk 1:100,000-scale Quadrangle. This quadrangle is located in southeastern corner of the PRB of Wyoming (**Figure 28**). To produce this map, existing mapping will be edited and compiled at the scale of 1:100,000 and any identified areas representing gaps in map coverage or outdated mapping will be mapped using air photos and limited field work.

The quadrangle includes bedrock ranging in age from Precambrian to Holocene. The northern part of the Hartville uplift consisting of a series of north-northeast oriented structures extends into the southwestern and south central parts of the quadrangle. The southeastern part of the quadrangle includes outcrops of Tertiary units offset by northeast-trending faults with apparent recent movement. The Tertiary units also include the zone that hosts the uranium deposit at Crow Butte in Nebraska.

Completion of this map would augment southward expansion of the Northern Powder River Basin geologic, hydrologic, and water quality database project, as well as helping complete 1:100,000-scale mapping in the southeastern quadrant of Wyoming. This mapping will also support industrial mineral and oil and gas exploration and development. Two of the three stated mapping priorities are addressed by this project. Requested funding will be used for the salary of one geological/GIS contract employee, travel and field vehicle costs, and supplies necessary to produce electronic and paper copies of the map and report.

The proposal submitted to STATEMAP 2005, included a total budget of $127,986 for completion of the four subprojects. The STATEMAP Review Panel recently announced the awards for STATEMAP 2005; the WSGS was awarded $94,804. The WSGS has now received a total of $584,305 from the STATEMAP Program since becoming involved in 1995. This year the review panel received 46 proposals requesting over $8.6 million, up over $200,000 from last year. Unfortunately, the National Cooperative Geologic Mapping Program was cut again this year and funding for STATEMAP 2005 was reduced to $6.1 million, down over $300,000 from STATEMAP 2004. Although the technical quality of proposals was high, they were unable to fully fund any proposal. The funding was tied to the review panel's score for each proposal. As a result of this reduction in funding, the WSGS will complete proposed subprojects 1, 2, and 3 with the funds allotted. The Lusk map (subproject 4) will be completed using other funding sources.

Tate Museum 2005 conference

The Casper College Tate Museum has announced the theme and dates for their annual field conference in Casper.

The announced conference theme is: "The Cretaceous-Paleocene K-T Boundary: Adaptive radiation after the bottleneck" and it will take place on June 3, 4, and 5, 2005. Saturday, June 4 will be devoted to talks emphasizing geology and paleontology topics centered on the conference theme. A field trip to visit the K-T boundary near Casper is scheduled for Friday, with a reception and keynote address that evening. Speakers scheduled to date include Neal Larson of the Black Hills Institute, Michael Everhart of Fort Hayes State, Kraig Derstler of the University of New Orleans, Jean-Pierre Cavigelli of the Tate Museum, Tom Kaye of Illinois, Doug Nichols of the USGS, and Roger Sawyer of the University of South Carolina. The opening keynote speaker will be Kirk Johnson of the Denver Museum of Nature and Science and the closing keynote speaker will be Karl Osvald of Casper. There will be the usual fossil collecting trip on Sunday.

The Tate Museum is celebrating its 25th anniversary this year and area geologists, paleontologists, and Museum supporters are urged to join in this celebration. For information on conference registration, field trips, and updated information on speakers and titles of their talks, check the Tate Museum Web site at: http://www.caspercollege.edu.

New publications on Wyoming geology

In a recently published article, Banerjee and Mitra (2004) described a new technique for remote surface mapping with the aid of orthophotos and geologic maps draped over digital elevation models (DEMs) in GIS. Formational contacts can be mapped by viewing the intersections of these contacts with topography presented as a three-dimensional digital image which is true-to-scale. Bedding attitudes can be determined from either the trends and slopes of dip slopes or best fit planes to multiple points of intersection of a bedding surface with the topography. The authors tested this approach against traditional mapping techniques used for published geologic maps of Sheep Mountain anticline in the Bighorn Basin of Wyoming. Bedding attitudes produced by this technique showed a close correlation with field measurements and detailed mapping of formation contacts is improved by careful observations of the contacts projected on the DEM. The described technique provides an accurate and efficient alternative to stereoscopic mapping using aerial photographs or satellite images, especially in remote, inaccessible areas.

Shanley and others (2004) recently published an article summarizing the results of their study of factors controlling prolific gas production from low-permeability sandstone reservoirs in the Greater Green River Basin (GGRB) of southwestern Wyoming. The authors examined significant large gas fields in the basin and concluded that they all occur in conventional structural, stratigraphic, or combination traps. The authors presented evidence that the GGRB is neither regionally gas saturated, nor is it near irreducible water saturation. Water production is common and widespread in the basin. Effective permeability of these reservoirs to gas is a function of both varying water saturation and overburden stress. These parameters must be understood and defined in order to predict gas-field distribution and individual well and reservoir performance. The authors suggested that the evaluation techniques successful in the GGRB should be used to evaluate similar systems in other basins.

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Shanley, K.W., Cluff, R.M., and Robinson, J.W., 2004, Factors controlling prolific gas production from low-permeability sandstone reservoirs: Implications for resource assessment, prospect development, and risk analysis: American Association of Petroleum Geologists Bulletin, v. 88, no. 8, p. 1083-1121.

Annual Field Trip, 2004

Richard W. Jones, Wyoming PG-2972

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After a four-year hiatus, the Wyoming State Geological Survey (WSGS) revived its annual public field trip on September 16 and 17, 2004. Entitled *Depositional environments of the Green River and Wasatch formations (Early Eocene) in the Greater Green River Basin, southwestern Wyoming,* the field trip was lead by Dr. Ronald C. Surdam, then Interim Director of the WSGS (later appointed Director and Wyoming State Geologist by Governor Freudenthal). The annual field trip is designed to acquaint the public with the state's geologists, geology, and mineral resources by visiting geologically interesting parts of Wyoming and surrounding areas.

The trip began in Rawlins on a typical Wyoming day in September: cloudless, dry, and windy. A group of 28 participants in a variety of pick-ups, carry-alls, and SUVs formed a caravan and headed westward on I-80 for the Washakie Basin. Crossing the Continental Divide just west of Rawlins, the group entered the Red Desert, an area completely encircled by the Continental Divide where no drainages leave and the reddish rocks of the Eocene Wasatch Formation crop out amongst the sand dunes, ephemeral lakes, intermittent streams, cactus, and sagebrush. After forty miles we arrived at the busy town of Wamsutter, and after crossing the rail-

road tracks of the Union Pacific (UP) at the edge of town, the caravan proceeded southward on a well-traveled gravel (dirt) road, heading into the Washakie Basin. We would not see another paved road until the very end of the day. This part of the basin contains a number of large natural gas fields being developed, and well locations dotted the area practically as far as the eye could see.

We began a day-long traverse through a series of depositional environments and subenvironments of the Wasatch and Green River formations, beginning with an alluvial sequence of red and green mudstones at the margin of a large lake system and ending with lacustrine oil shales (laminated carbonates) within the lake. We examined a well-exposed sequence of rocks that preserved a record of both very wet and very dry periods. During the wet periods, a huge freshwater lake system called Lake Gosiute occupied a large part of southwestern Wyoming, northeastern Utah, and northwestern Colorado. The lake supported a complex biosystem of plant and animal life, and we saw fossil evidence of this practically everywhere, ranging from simple algal mats to the highest plants and from snails to catfish and flamingos. During the dry periods, the lake almost completely disappeared, except for restricted areas where hypersaline conditions existed, depositing evaporite minerals such as trona, which are underground mined today west of Green River.

Most of the field trip participants had never seen this complex sequence of rocks in the detail that Dr. Surdam demonstrated at the different stops, and he was very knowledgeable about all aspects of the rocks. Dr. Surdam (most call him "Ron" except for some of his former students) has spent a significant part of his professional career studying these rocks and supervising a number of University of Wyoming graduate theses on them, as well as publishing a number of scientific papers on the Green River Formation. It was enlightening to see what could actually be determined about the ancient environments from examining the rocks in detail, especially because when seen from a distance, the rocks just do not appear that interesting. Ron gave all the participants a deep appreciation for careful and detailed study and how this can lead to important conclusions and interpretations about a lake and its surroundings that existed 50 million years ago.

The first stop was the upper part of the Cathedral Bluffs Tongue of the Wasatch Formation. The rocks here represent alluvial plains (variegated redbed lithofacies), and poorly drained alluvial plains (**Figure 29**) and mudflats (green mudstone lithofacies) on the edge of a lake. Some lake (lacustrine) and strandline deposits of the Laney Member of the Green River Formation representing the laminated carbonate lithofacies were seen here, evidence that Lake Gosiute was present and the Green River Formation had started to form. This stop showed how a lake system developed as the climate became wetter (**Figure 30**). From here, the field trip moved up section (and uphill) to the top of Delaney Rim, a topographic feature that gave us some spectacular views to the east and north (**Figure 31**). The rim is help up by resistant rocks of the Laney Member of the Green River Formation. We followed the edge of this rim for a number of miles, and at stop 2 examined more facies in the Cathedral Bluffs Tongue, as well as observing some low-grade oil shales in the Laney Member.

Figure 29. Cathedral Bluffs Tongue of the Wasatch Formation (these are red beds that appear dark on a black and white photograph) overlain by Laney Shale Member of Green River Formation (lighter rocks on top right) on eastern edge of the Washakie Basin. Photograph by Mario Slavinec, September 2004.

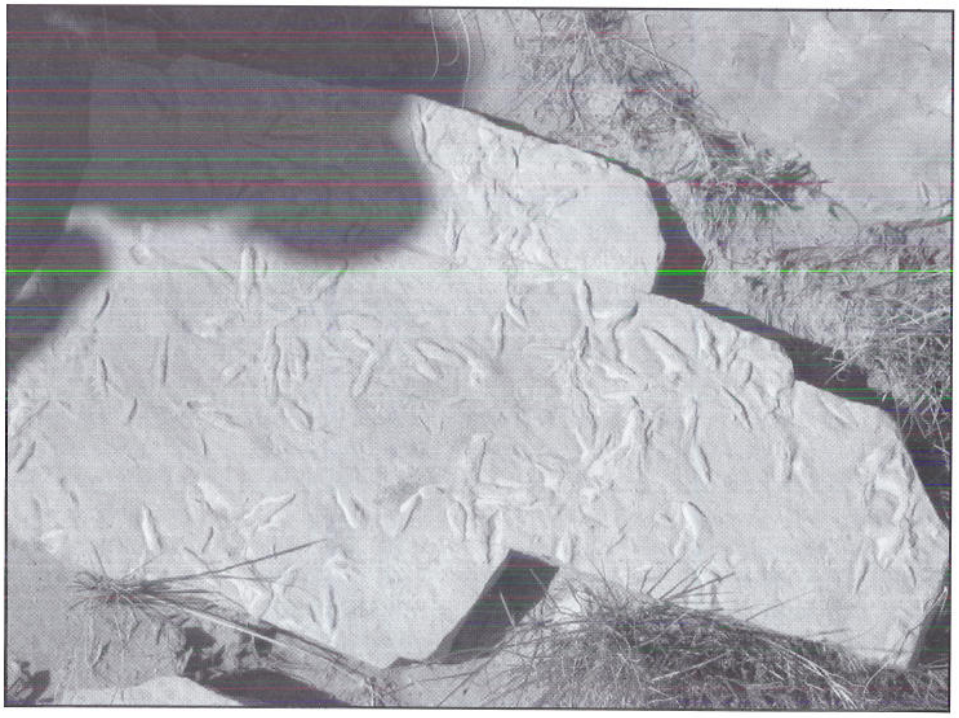

Figure 30. Fossilized flamingo tracks in the Laney Member of the Green River Formation.

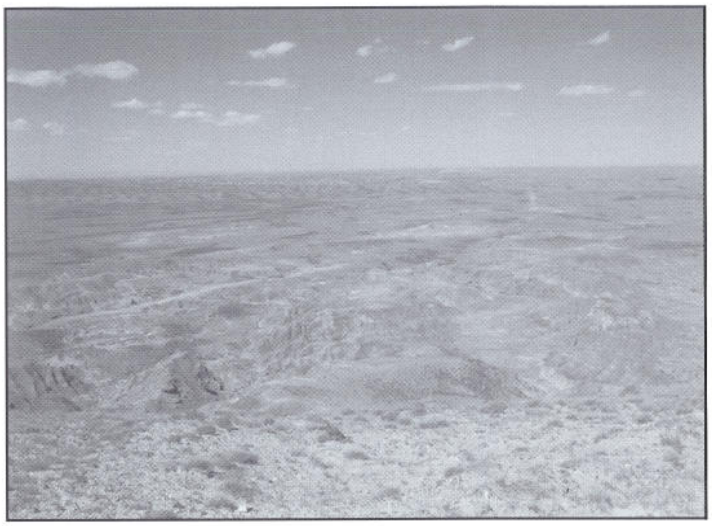

Figure 31. View to north towards Tipton Road from top of Delaney Rim, northern Washakie Basin. Standing on Laney Member of Green River Formation; middle part of photograph is variegated red beds of Cathedral Bluffs Tongue of Wasatch Formation. Photograph by Mario Slavinec, September 2004.

Several miles to the south of Delaney Rim and stratigraphically above the Laney Member, we could see outcrops of the Eocene Washakie Formation, which comprises nearly all the bedrock in the center of the Washakie Basin (along with extensive Quaternary sand dunes). Very few of the field trip participants had ever seen the interior of the Washakie Basin or the pond, small lake, and alluvial deposits of the Washakie Formation (equivalent to the Bridger Formation which crops out above the Laney Member west of the Rock Springs uplift). At our third stop, on the western part of Delaney Rim, we looked at a repetitive sequence of laminated carbonate facies in the Laney, including some of the richer oil shales. These were deposited along the eastern margin of Lake Gosiute.

A few miles south of the third stop, Ron lead us to what he claimed to be "probably the most spectacular exposure of a classic Gilbert-type delta sequence anyone would ever see"—and it was. At this the fourth stop, one could see classic bottomset, foreset, and topset sandstone beds of the delta complex that formed when a sediment-laden stream flowed into the standing water of Lake Gosiute. Also preserved were features where parts of the delta were destroyed by wave action on the edge of the lake. The lake depth was estimated at about 25 meters based on maximum thickness of foreset beds in the delta. Every geologist that studies sedimentary structures and deposits should visit these outcrops some time in their careers, because one can see all the parts of a classic delta in one place, all at once.

The last stop of the day was to view laminated carbonate (oil shale) lithofacies of the Laney, again near the eastern margin of Lake Gosiute. Here were excellent exposures of stromatolites (**Figure 32**), pisolites, and other features of the oil shale sequence. As we started back north to I-80, we entered the drainage of Bitter Creek, along which the Overland Trail followed. Our previous stop to view the delta was

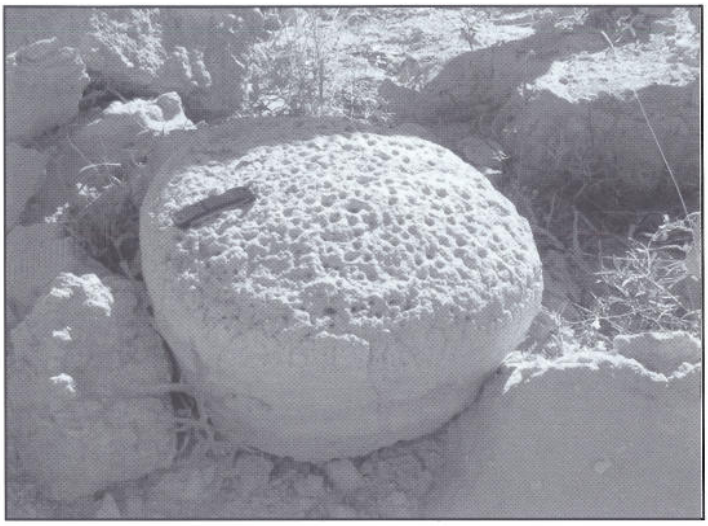

Figure 32. Fossil stromatolite near base of Laney Member of Green River Formation on Delaney Rim, northern Washakie Basin. Photograph by Mario Slavinec, September 2004.

just a short distance northwest of the old La Clede stage station on the trail. Continuing north, we once again crossed the UP tracks, this time at Bitter Creek siding, and then to I-80 where we headed west to Rock Springs for an awaiting barbecue dinner and several well-deserved malt beverages.

The next day we headed west on I-80 to Green River. On the way, we observed all three members of the Green River Formation on White Mountain north of I-80 and on Wilkins Peak south of the I-80: Tipton Shale Member (lowest), Wilkins Peak Member (middle), and Laney Member (highest). The caravan threaded its way southward through Green River and its suburbs to Stop 6 (**Figure 33**). In contrast to the day before when we examined rocks on the eastern margin of Lake Gosiute, this stop was near the depositional center of the lake. We examined the restricted evaporative Wilkins Peak Member (**Figure 34**) and both laminated carbonate facies (kerogen-rich and kerogen-poor) and evaporite facies of the Laney (**Figure 35**), and at the top of the sequence, volcanic

Figure 33 (upper right). View to southeast from top of Buff Marker Bed in Laney Member 5 miles south of town of Green River. Oil shales of Laney on ridge in center of photograph, Wilkins Peak Member is exposed where vehicles are parked. Photograph by Mario Slavinec, September 2004.

Figure 34. Outcrops of Wilkins Peak Member of Green River Formation 5 miles south of Green River town site. Photograph by Mario Slavinec, September 2004.

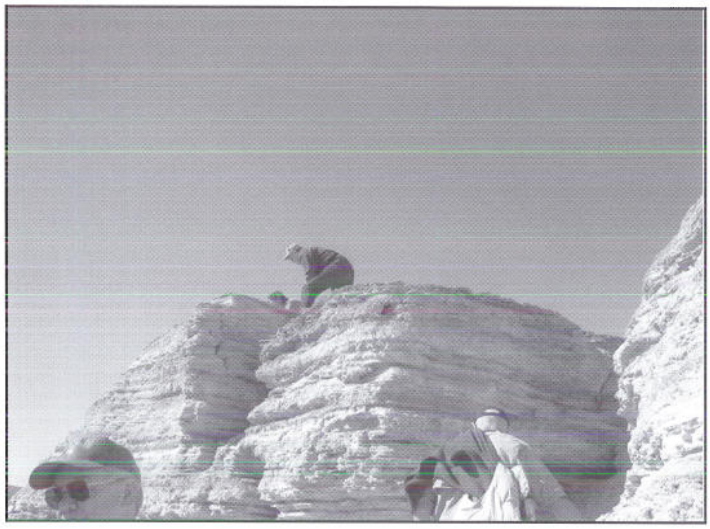

Figure 35. Transitional zone from top of Wilkins Peak Member to base of Laney Member 5 miles south of Green River town site. Persons on top of outcrop are looking for fossil fish in the Laney. Photograph by Mario Slavinec, September 2004.

lithic sandstone in the upper part of the Laney (**Figure 36**). We then returned to Green River, and after a short time at the Flaming Gorge Visitor Center, proceeded south on Wyoming 530 nearly to the Utah border.

At Stop 7 just north of Linwood Bay on Flaming Gorge Reservoir, we examined the Green River and Wasatch formations near the frontal fault of the Uinta Mountains. Alluvial fan and braided stream deposits (mostly conglomerates and red sandstones) (**Figure 37**) shed off the tectonically active Uinta Mountains interfinger with strandline and lacustrine carbonates of the Green River Formation. We observed a thick fossil soil horizon (paleosol) at this stop, which according to Dr. Surdam is "an outstanding example of a fossil soil exposed practically anywhere" (**Figure 38**). This stop was very near the southern edge of Lake Gosiute; our Stop 8 was slightly farther north into the lake environment, where delta fans of sandstone (downstream from the braided streams and alluvial fans) entered the lake, interfingering with the laminated carbonate lithofacies (**Figure 39**). A short distance east of here, Ron pointed out some large carbonate tufa mounds that apparently formed in the lake where calcium-rich waters entered Lake Gosiute along deep fractures, probably in a situation similar to modern features seen along Pyramid Lake in California. A few miles even farther north at Stop 10 along Highway 530 we observed more laminated carbonate deposits (poor-grade oil shale probably near the lake margin).

After these stops near the southern margin of Lake Gosiute, the field trip caravan headed back north on Highway 530, paralleling the Green River and Flaming Gorge Reservoir. At the town of Green River, we turned east and returned to Rock Springs where part of the participants separated and headed back home. The "die-hards" on the field trip continued on to White Mountain directly west of Rock Springs where Ron lead us through exposures of the Tipton Shale Member (**Figure 40**), the first major evidence of the Green River Formation in this area. A thin unit called the Luman Tongue or Member of the Green River Formation occurs south of this area and stratigraphically below the Tipton. The field trip concluded with this final stop halfway up the steep side of White Mountain.

All those that attended the field trip appreciated a leader of Dr. Surdam's caliber. The technical content, while a little much for some participants, was appropriate for the group and Ron did an excellent job of explaining the technical details for the laymen. The Green River Formation remains one of the most fascinating and challenging rock sequences in the world, but outside the geologic and paleontologic community, it is practically unknown even to most Wyoming residents. But it must be seen to be appreciated!

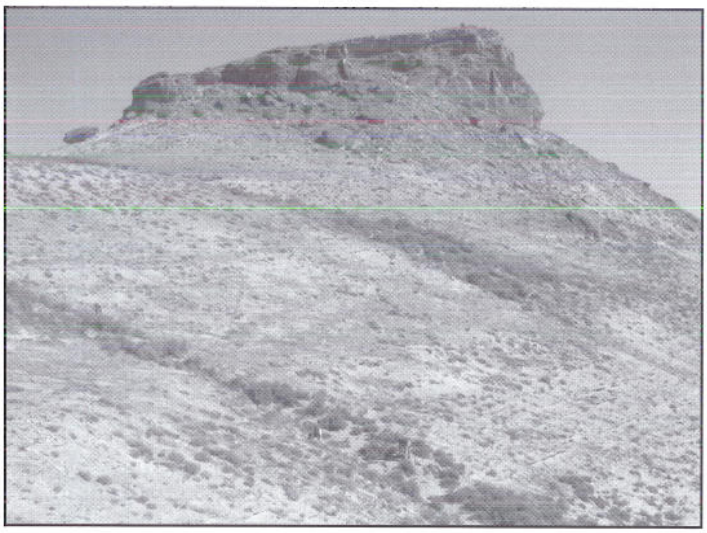

Figure 36. Upper part of Laney Member of Green River Formation 5 miles south of Green River town site contains volcanic sandstone (dark outcrops on horizon) above oil shale sequence. This sandstone (often called the Tower Sandstone) represents alluvial deposits marginal to lacustrine deposits. Photograph by Mario Slavinec, September 2004.

Figure 37 (right). Arkosic sandstones and conglomerates (darkest beds that are shades of red in color photographs) and quartzose sandstones and conglomerates (lighter colored and white beds) of Wasatch Formation near Wyoming/Utah state line east of Manila, Utah. Some carbonate strandline and lacustrine rocks of the Green River Formation are interbedded with these coarse grained rocks. Photograph by Mario Slavinec, September 2004.

Figure 38 (center). Thick paleosol lies above weathered top of white quartz sandstone and below the reddish sandstone. Wasatch Formation north of Wyoming/Utah state line was deposited on edge of Lake Gosiute along tectonically active Uinta Mountain front. Photograph by Mario Slavinec, September 2004.

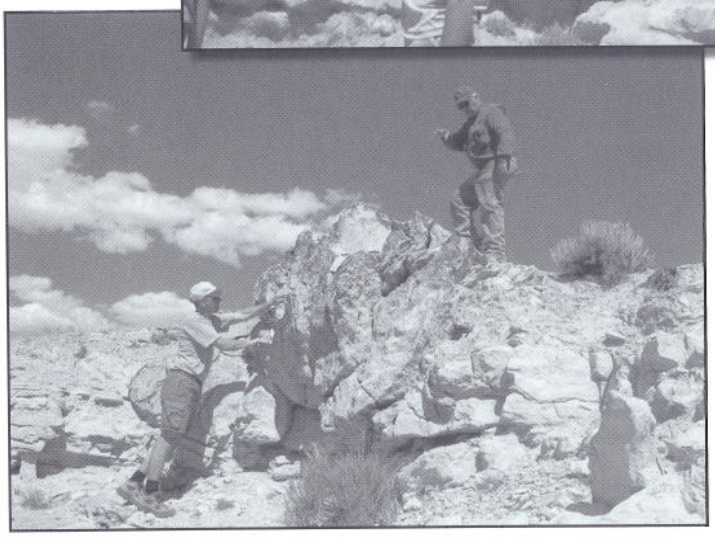

Figure 39. Algal tufa mounds in oil-shale poor Laney Member formed near the edge of Lake Gosiute. Field trip leader Ron Surdam explains how these form to Joe Huss, GIS coordinator for the WSGS. Photograph by Mario Slavinec, September 2004.

Figure 40. Tipton Shale Member of the Green River Formation exposed on east flank of White Mountain west of Rock Springs. Photograph by Mario Slavinec, September 2004.

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Wyoming State Geological Survey publications

*Wyoming State Geological Survey publications catalog, March 2005: Available on CD-ROM or 40 p. printed catalog or CD-ROM - FREE.

*Field guide for the Alcova area, Natrona County, Wyoming: P. Knittel, D. Van Burgh, T. Logue, B. Struve, and R. Jones, 2005, 90 p. - $15.00.

Geologic map of the Nowater Creek 30′ x 60′ Quadrangle, Washakie, Hot Springs, and Johnson Counties, Wyoming, by A.J. Ver Ploeg, 2004: Map Series MS-39, 1:100,000 - $25.00.

Industrial minerals and construction materials map of Wyoming, by R.E. Harris, 2004: Map Series MS-47, 1:500,000 - $30.00.

*Coalbed methane activity in the eastern Powder River Basin, Campbell and Converse counties, Wyoming, by R.H. De Bruin, R.M. Lyman, L.L. Hallberg, and N.R. Jones, 2005: Map Series 56 (updated to March 1, 2005, replaces September, 2004 version), on-demand plotted color map, rolled only - $30.00.

*Coalbed methane activity in the western Powder River Basin, Campbell, Converse, Johnson, Natrona, and Sheridan counties, Wyoming, by R.H. De Bruin, R.M. Lyman, L.L. Hallberg, M.M. Harrison, and N.R. Jones, 2005: Map Series 57 (updated to March 1, 2005, replaces September, 2004 version), on-demand plotted color map, rolled only - $30.00.

*Coalbed methane activity in the Powder River Basin, Campbell, Converse, Johnson, Natrona, and Sheridan counties, Wyoming, by R.H. De Bruin, R.M. Lyman, L.L. Hallberg, M.M. Harrison, and N.R. Jones, 2005: Map Series 58 (this is a reduced and combined version of MS-56 and MS-57 at 1:250,000 scale, updated to September 1, 2004, replaces March, 2004 version), on-demand plotted and laminated color map, rolled only - $50.00; on-demand plotted color map, rolled only - $40.00; ESRI® ArcGIS®/ArcReader® format on CD-ROM (including MrSid® viewable files) - $50.00.

Geologic map of the Reno Junction 30′ x 60′ Quadrangle, Campbell and Weston counties, Wyoming, by A.J. Ver Ploeg and C.S. Boyd, 2003: Map Series 62 (scale 1:100,000), plotted color map, rolled only - $25.00.

Geologic map of the Kaycee 30′ x 60′ Quadrangle, Johnson and Campbell counties, Wyoming, and southeastern Montana, by A.J. Ver Ploeg, C.S. Boyd, and J.M. Mulbay, 2004: Map Series 63 (scale 1:100,000), plotted color map, rolled only - $25.00.

Geologic map of the Sheridan 30′ x 60′ Quadrangle, Sheridan, Johnson, and Campbell counties, Wyoming, and southeastern Montana, by A.J. Ver Ploeg and C.S. Boyd, 2003: Map Series 64 (scale 1:100,000), plotted color map, rolled only - $25.00.

Structure contour and isopach maps of the Fox Hills Sandstone, northern Powder River Basin, northeastern Wyoming, by R.H. De Bruin, A.J. Ver Ploeg, R.M. Lyman, N.R. Jones, and J.C. Case, 2003: Open File Report 03-1, plotted color map and text, 1 sheet, rolled only - $10.00.

Structure contour and isopach maps of the Lance Formation, northern Powder River Basin, northeastern Wyoming, by A.J. Ver Ploeg, R.H. De Bruin, R.M. Lyman, N.R. Jones, and J.C. Case, 2003: Open File Report 03-2, plotted color map and text, 1 sheet, rolled only - $10.00.

Structure contour and isopach maps of the Bearpaw/Pierre Shale, northern Powder River Basin, northeastern Wyoming, by R.M. Lyman, R.H. De Bruin, A.J. Ver Ploeg, N.R. Jones, and J.C. Case, 2003: Open File Report 03-3, plotted color map and text, 1 sheet, rolled only - $10.00.

Structure contour and isopach maps of the Fort Union Formation, northern Powder River Basin, northeastern Wyoming, by N.R. Jones, R.M. Lyman, A.J. Ver Ploeg, R.H. De Bruin, and J.C. Case, 2003: Open File Report 03-4, plotted color map and text, 1 sheet, rolled only - $10.00.

Preliminary surficial geologic map of the Midwest 30′ x 60′ Quadrangle, Natrona, Converse, and Johnson counties, Wyoming, by L.L. Hallberg and J.C. Case, 2003: Open File Report 03-5 (scale 1:100,000), plotted color map, rolled only - $25.00.

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Carbon dioxide (CO_2) map of Wyoming, by R.H. De Bruin, C.W. Cook, and J.M. Huss, 2004: Open File Report 04-1 (scale 1:500,000), plotted color map, rolled only - $30.00.

Wyoming multi-hazards flood map modernization state business case plan FY 2004-2008, by J.C. Case and E.A. Dobler, 2004, Open File Report 04-2, 28 pages copied - $4.20.

Preliminary surficial geologic map of the Nowater Creek 30′ x 60′ Quadrangle, Washakie, Hot Springs, and Johnson Counties, Wyoming, by L.L. Hallberg and J.C. Case, 2004: Open File Report 04-3, 1:100,000 - $25.00.

Preliminary surficial geologic map of the Chugwater 30′ x 60′ Quadrangle, Wyoming, by J.C. Case and L.L. Hallberg, 2004: Open File Report 04-4, 1:100,000 - $25.00.

Geologic map of the Kinney Rim 30′ x 60′ Quadrangle, Sweetwater County, Wyoming and Moffat County, Colorado, by H.W. Hoehler, 2004: Open File Report 04-5, 1:100,000 - $25.00.

Geologic map of the Evanston 30′ x 60′ Quadrangle, Uinta and Sweetwater Counties, Wyoming, by J.H. Dover and J.W. M'Gonigle, 2004: Open File Report 04-6, 1:100,000 - $25.00.

Geologic map of the Kemmerer 30′ x 60′ Quadrangle, Lincoln, Uinta, and Sweetwater Counties, Wyoming, by J.W. M'Gonigle and J.H. Dover, 2004: Open File Report 04-7, 1:100,000 - $25.00.

*Preliminary geologic map of the Casper 30′ x 60′ Quadrangle, Natrona and Converse counties, central Wyoming: J. Hunter, A.J. Ver Ploeg, and C.S. Boyd, 2004, 12 p. and one color sheet rolled only- $10.00.

Geologic map of the Saratoga 30′ x 60′ Quadrangle, Wyoming (b&w version), by W.M. Sutherland and W.D. Hausel, 2004: Open File Report 04-10, 1:100,000 - $25.00.

Geologic map of the Saratoga 30′ x 60′ Quadrangle, Wyoming (color version), by W.M. Sutherland and W.D. Hausel, 2004: Open File Report 04-10, 1:100,000 - $35.00.

*Preliminary geologic map of the Torrington 30′ x 60′ Quadrangle, Goshen and Platte counties, Wyoming and Scotts Bluff and Sioux counties, Nebraska: F. McLaughlin and R.E. Harris, 2004, plotted color map, rolled only - $10.00.

Geologic map of the Hole-in-the-Wall 1:24,000-scale Quadrangle, Johnson County, Wyoming, by A.J. Ver Ploeg, 2004: Open File Report 04-12, plotted color map, rolled only - $10.00.

Geologic map of the Poker Butte 1:24,000-scale Quadrangle, Johnson County, Wyoming, by A.J. Ver Ploeg, 2004: Open File Report 04-13, plotted color map, rolled only - $10.00.

Geological reconnaissance of the Grizzly Creek gemstone deposit, Laramie Mountains, Wyoming—Potential source for iolite, sapphire, ruby, and kyanite, by W.D. Hausel and W.M. Sutherland, October, 2004: Open File Report 04-14 - $4.00.

*New releases since *Wyoming Geo-notes No. 80* (June, 2004).

National Geographic maps

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.

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

Other publications

Wildflowers of Wyoming, by D. States and J. States, 2004: Mountain Press Publishing Company, Missoula, Montana - $19.00.

Sagebrush Country—A wildflowers sanctuary, by R.J. Taylor, 1992: Mountain Press Publishing Company, Missoula, Montana - $14.00.

Roadside history of Wyoming, by C. Moulton, 1995: Mountain Press Publishing Company, Missoula, Montana - $18.00.

A dinosaur dynasty, by K. Rogers, 1999: Mountain Press Publishing Company, Missoula, Montana - $14.00.

Roadside history of Yellowstone Park, by W. Blevins, 1989: Mountain Press Publishing Company, Missoula, Montana - $10.00.

Ice age mammals of North America—A guide to the big, the hairy, and the bizarre, by I.M. Lange, 2002: Mountain Press Publishing Company, Missoula, Montana - $20.00.

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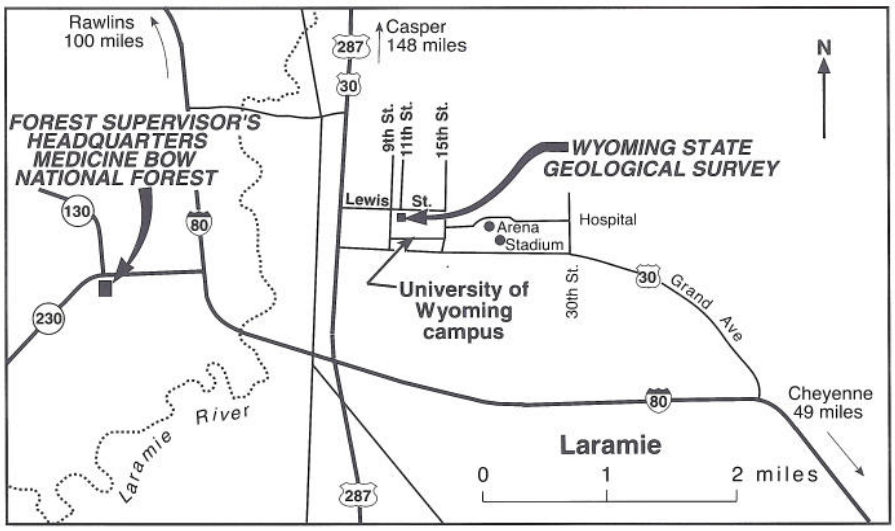

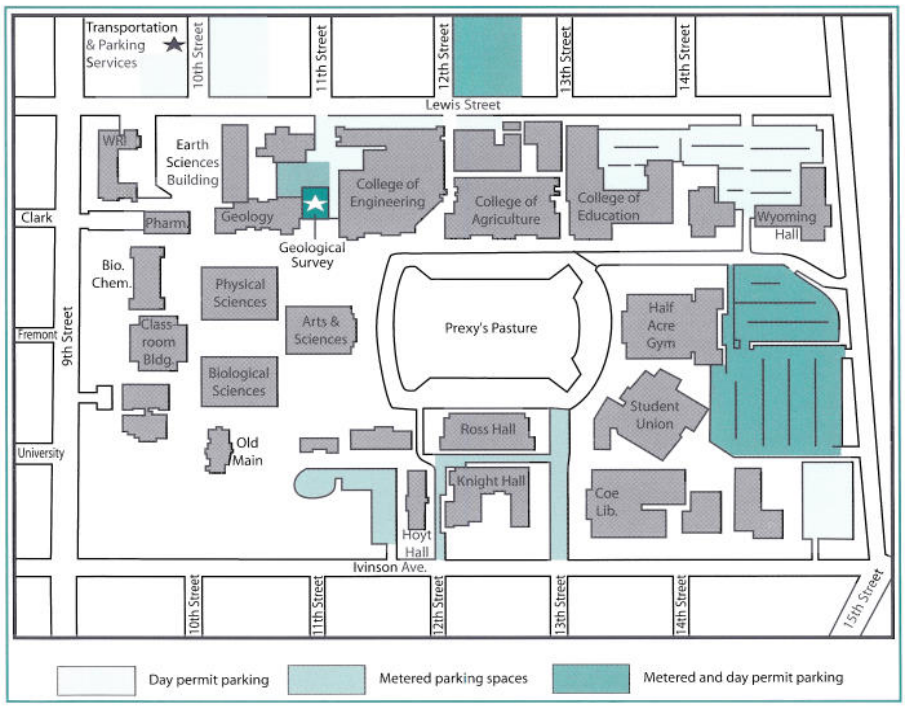

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