THE GEOLOGICAL SURVEY OF WYOMING
Gary B. Glass, State Geologist

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WYOMING GEO-NOTES

This quarterly digest on the State's geology and mineral resources and activities of the Geological Survey is available by subscription (four issues for $5.00) or as single copies at $1.50 each. Two-year subscriptions are accepted.

The cover on this issue of *Wyoming Geo-notes* represents the Geological Survey's new microcomputer system. The improved format in the previous three issues of this newsletter were made possible by the acquisition of our new Macintosh microcomputers. We hope you are as pleased with the new look as we are.

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Table of Contents

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MINERALS UPDATE

OVERVIEW

by Gary B. Glass, State Geologist, Geological Survey of Wyoming

Perhaps the biggest news in the fourth quarter was the strength of oil prices. By the end of December, posted prices for Wyoming Sweet had gone over $19.00 and the new year saw them topping $20.00. The average posted price for Wyoming Sweet in 1989 was approximately $18.26, up $3.24 from 1988. If the price would stabilize above $18.00 for a long enough time, some of the planned secondary and tertiary recovery projects in Wyoming might come out of their mothballed status. Since the average posted price exceeded $18.00 in nine of the last 10 months of 1989, there is room for some optimism.

Our estimate of 108 million barrels of oil production from Wyoming in 1989 is still looking good (Table 1). Don Basko, Supervisor for the Wyoming Oil and Gas Conservation Commission, has estimated it a little higher at 108.65 million barrels. In either case, 1989 production will still be more than 5.5 million barrels below 1988. It would not, however, take but a few new secondary or tertiary recovery projects to reduce the slope of this production decline.

There is also some good news regarding the price for combustible natural gas. The spot gas price at Opal has risen from $1.05 earlier this year to $1.65. This helps substantiate the opinion that the gas glut or bubble of the past is fast disappearing. This opinion is further supported by some spot shortages of natural gas that occurred in some parts of the country during the extremely cold days near the end of the year.

With the end of the gas glut in sight and the likelihood of a pipeline from Wyoming to California in the near future, it is not surprising that more than half of the rigs running in Wyoming in the last quarter were in the gas fields of the southwestern portion of the State. Admittedly, most of these rigs were not drilling exploration wells. They were drilling development or infill wells in or around existing fields. Still, they provided jobs and many proved up or developed existing reserves. Some even found new reserves.

It is still quite possible that the State's 1989 gas production will reach our estimate of 815 billion cubic feet (Table 1). On the down side, however, it may slip to as low as 810 billion cubic feet, which is about 1.6 billion cubic feet less than production in 1988. Only the year-end figures will answer this one.

In regard to coal, our predicted 170 million tons in Table 1 should be very close to the mark. The State's retention of its first place standing in coal production is about as sure as it could be before the actual figures are tabulated. In addition, potential markets for the State's coal were extended in the last quarter when a Kentucky utility

company conducted a successful test burn of coal from the Powder River Basin of Wyoming. The utility is looking for a hedge against costly new pollution-control devices that might be needed to comply with anticipated Federal legislation regarding acid rain. On the down side, the price paid for a ton of spot coal from the Powder River Basin still did not show any significant improvement.

Looking at other mineral industries of the State, trona production finished the year very strong as did production from Wyoming's one cement plant. Helium production remained stable as did the new burgeoning sulfur industry. Of the state's that produce sulfur as a by-product of natural gas production, Wyoming now ranks second. With the exception of uranium, most of the other mineral industries apparently held their own or increased production somewhat in 1989. Even uranium had an up side in that production from solution-mining operations increased again in 1989. Although the last of the conventional uranium open pit mines quit producing uranium in late 1989, the mine was not actually shut down. In anticipation of its reopening in the near future, the mine is still removing overburden from above the ore.

The bottom line is actually better than it was at the end of the third quarter because not only did the prospects for increased production of most mineral and energy resources occur, but also the price of oil increased through the end of 1989 and into the new decade.

Table 1. WYOMING MINERAL PRODUCTION FORECAST TO 1993[1].

Calendar Year	Oil Production[2]	Methane Production[3]	Carbon Dioxide Production[3]	Helium Production[4]	Coal Production[5]	Trona Production[5]	Mined Uranium Production[6]	In situ Uranium Production[7]	Sulfur Production[8]
*1981	122.1	455.4	—	—	102.8	11.8	4.6	—	0.05
*1982	118.7	465.1	—	—	107.9	10.1	2.1	—	0.07
*1983	120.9	539.7	—	—	112.2	10.5	3.0	—	0.57
*1984	127.8	600.1	—	—	130.7	11.0	1.6	—	0.63
*1985	131.0	597.9	—	—	140.4	10.8	0.6	—	0.80
*1986	122.4	563.2	23.8	0.15	136.3	13.3	0.3	—	0.66
*1987	115.9	622.7	110.5	0.84	146.5	13.6	0.2[9]	0.06	1.20
*1988	114.3	701.1	110.5	0.84	163.6	14.9	0.3	1.4	1.20
1989	108.0	704.5	110.5	0.84	170.0	15.0	0.2	2.0	1.20
1990	103.6	729.0	110.5	0.84	177.1	18.0	0.2	2.0	1.20
1991	96.1	754.1	110.5	0.84	183.6	18.0	0.1	3.0	1.20
1992	92.9	780.1	110.5	0.84	189.2	18.0	0.1	3.5	1.20
1993	88.0	806.8	110.5	0.84	193.1	21.0	0.1	4.0	1.20

*Actual values for comparison; [1]Geological Survey of Wyoming, October 1989; [2]millions of barrels; [3]billions of cubic feet; [4]billions of cubic feet, based on Exxon's estimate that the average helium content in the gas processed at Shute Creek is 0.5 percent; [5]millions of tons; [6]millions of tons of uranium ore (not yellowcake); [7]millions of pounds of yellowcake (U_3O_8), (unknown between 1981-1986 because it was reported only as taxable valuation; estimates for 1989-1993 are based on company information); [8]millions of tons, converted from gallons of sulfur produced at gas processing plants as reported to the Wyoming Oil and Gas Conservation Commission; [9]includes previously stockpiled ore processed by the Lucky Mc mill in 1987.

Table 2. PRODUCTION HISTORY OF SELECTED WYOMING MINERAL COMMODITIES[1].

	1980	1981	1982	1983	1984	1985	1986	1987	1988
Ballast[2,3]	1.65	1.72	0.81	0.99	2.43	0.67	0.61	1.09	NA[7]
Bentonite[2]	3.58	4.81	2.35	2.18	3.08	2.59	1.82	2.16	2.32
Clay[4]	42.0	23.2	15.7	36.4	59.6	35.9	23.2	1.31	61.1
Decorative Stone[2]	0.05	0.05	0.05	0.07	0.08	0.09	0.07	0.06	0.07[9]
Dolomite[2]	1.67	0.87	0.61	0.66	0.86	0.87	0.81	0.46	0.19[8]
Feldspar[4]	0.20	0.03	0.17	----	----	----	----	----	----
Gypsum[2]	0.30	0.28	0.26	0.33	0.33	0.35	0.41	0.35	0.40[9]
Iron Ore[2]	4.88	4.67	3.28	2.48	----	----	----	----	----
Limestone[2,5]	0.50	0.72	0.59	0.56	0.65	0.32	0.34	0.42	0.64
Sand and Gravel[2]	5.06	5.21	4.74	5.00	4.76	4.71	3.53	2.57	2.16
Scoria[2,6]	0.03	0.08	0.08	0.07	0.23	0.13	0.04	----	0.20[9]
Shale[4]	----	----	----	----	20.3	14.7	9.88	49.0	50.2[9]
Sodium Sulfate[4]	----	3.20	3.17	3.19	3.25	2.71	2.03	----	2.10[8]

Sources: [1]Ad Valorem Tax Division. [2] Millions of short tons. [3] Includes granite, scoria and other rock. [4] Thousands of short tons. [5] Includes limestone used for cement rock, sugar beet refining, and other uses. [6] Baked and fused rock, also called clinker [7]NA means not available. [8] Wyoming State Inspector of Mines. [9] Estimated by Geological Survey of Wyoming. Prepared by Geological Survey of Wyoming, December, 1989.

OIL AND GAS UPDATE

by Rodney H. De Bruin, Oil and Gas Division Head, Geological Survey of Wyoming

Average posted prices for Wyoming Sweet crude oil rose from a low of $16.40 per barrel in January, 1989 to a high of $19.50 per barrel in April, 1989. After April, the average monthly price fluctuated between $17.35 and $19.20 per barrel. The $19.20 average price was for December, 1989. Prices were more stable in 1989 than in 1987 or 1988 (Figure 1) and did not experience the sharp drop in the second half of the year that was characteristic of 1987 and 1988. While the average posted price for a barrel of Wyoming Sweet was $17.98 in 1987 and only $15.02 in 1988, it increased to $18.26 in 1989.

Although OPEC met in November, 1989 and set a production quota of 22 million barrels of oil per day for the first half of 1990, Kuwait and the United Arab Emirates are expected to exceed their quotas. OPEC members want an average price of $18 per barrel for their oil, which would translate into $20-$21 per barrel for Wyoming Sweet. It may be hard, however, to hold that price through the first half of 1990 because of the larger OPEC quota and anticipated increases in production from the North Sea.

The higher and more stable average prices for oil in the second half of 1989 were partly responsible for a relatively high rig count during the last four months of the year

(Figure 2). Overall, the rig count averaged 34 for 1989. The average yearly count has been essentially flat for the past four years (Figure 3). The rig count should be higher in 1990 due to increased drilling for conventional natural gas as well as for coalbed methane. There is a chance, however, that this anticipated increase could be tempered somewhat if crude oil prices decline because of overproduction in other parts of the world.

There is an exciting new project in Wyoming that will use a single-well, cyclic, carbon dioxide (CO_2) stimulation (huff n' puff) process. The Enhanced Oil Recovery Institute (EORI) of the University of Wyoming is cooperating with Wold Oil Properties Inc. of Casper to evaluate this process in Wyoming. The initial test well, the Crooks Gap No. 4, is located in Crooks Gap Field in NW SW section 18, T.28N., R.93W. The target for the project is the Dakota reservoir, which last produced oil in the Crooks Gap No. 4 well in July, 1966. Approximately 13.8 million cubic feet of carbon dioxide will be injected into the Dakota reservoir where it will be left to soak. After a three-week shut-in period, the well will be returned to production. If the well responds favorably, tertiary oil recovery may be in the range of 10,000-15,000 barrels of oil. The well should begin production in early 1990.

The EORI also plans to test the process in other wells in different geographic and geologic settings. If even some of these tests are successful, the process could have significant implications for Wyoming's oil industry. There are several thousand abandoned and(or) marginally economic oil wells in Wyoming that are candidates for the huff n' puff process and the technique is well-suited to smaller operators who

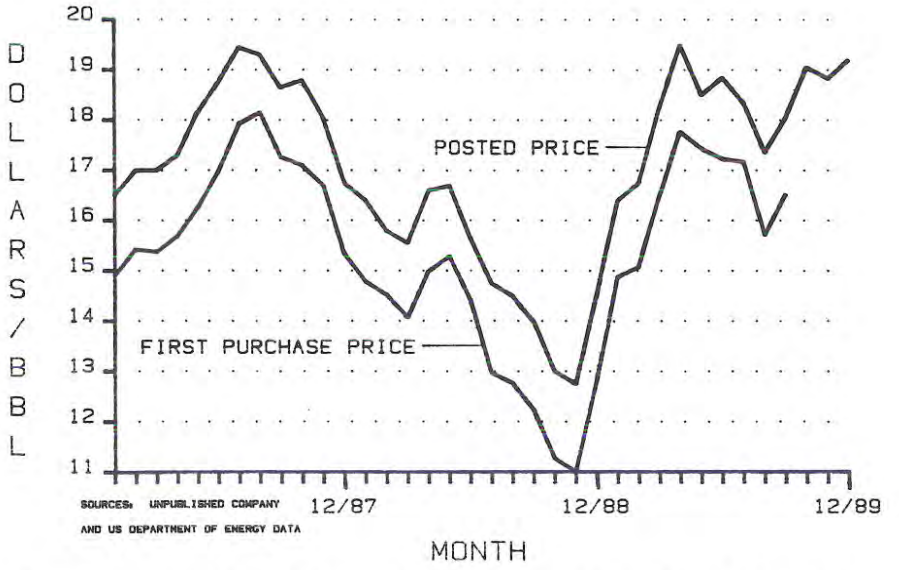

Figure 1. WYOMING CRUDE OIL PRICES AVERAGED BY MONTH (1987 TO PRESENT).

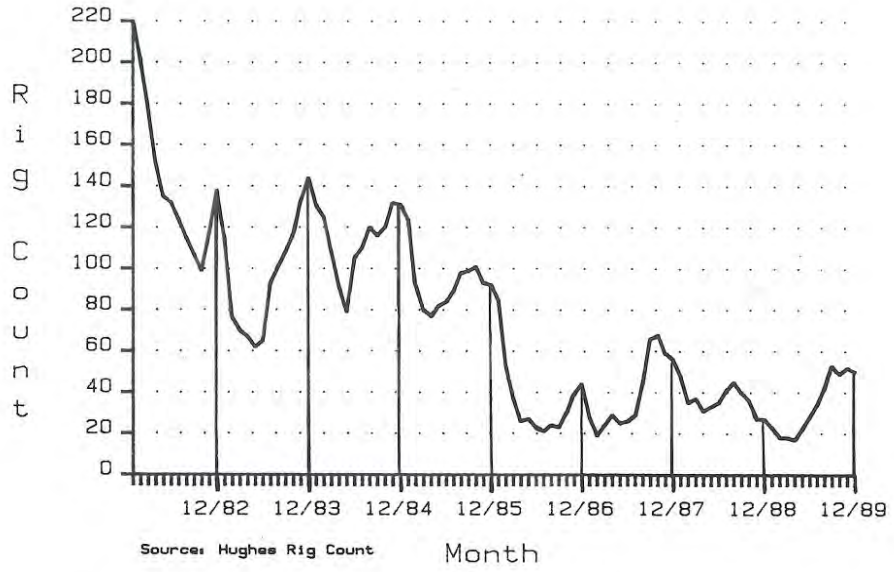

Figure 2. WYOMING RIG COUNT AVERAGED BY MONTH (1982 TO PRESENT).

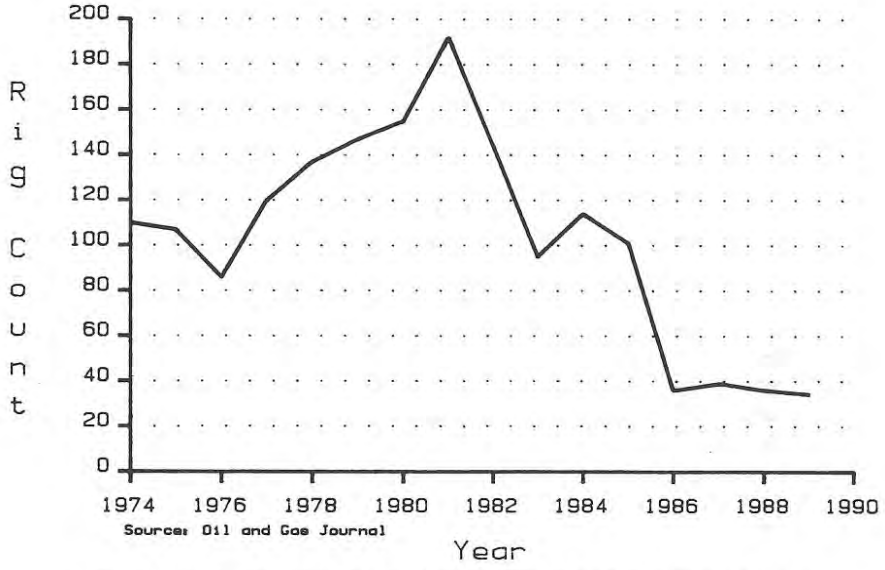

Figure 3. WYOMING RIG COUNT AVERAGED BY YEAR (1974 TO 1989).

can't afford the costs of a CO_2 flood. The huff n' puff method may not only help recover millions of barrels of oil that otherwise might be left in abandoned wells, but it may also create an additional market for Wyoming's huge CO_2 reserves.

In a related item, the Interstate Oil Compact Commission reported that 17,423 stripper wells were abandoned in 1988 in the United States. Of that total, there were 327 stripper wells abandoned in Wyoming or 9.4 percent of the stripper wells in the State. Some of these wells would have been candidates for the huff n' puff process and may still be for that matter.

Exxon now owns a 60 percent interest in Hartzog Draw Field, the second largest oil-producing field in the State. Earlier they purchased Bell Creek Field in Montana. With the purchase of these two fields and Exxon's large carbon dioxide reserves, there is some additional optimism that Exxon might flood the fields with carbon dioxide in the not too distant future.

Activity in the Green River Basin continues to accelerate. In December, the Wyoming Oil and Gas Conservation Commission approved Amoco's application for an optional, additional Dakota gas well per section in the Bruff, Fabian Ditch, and Verne Fields in southwest Wyoming. The area is comprised of slightly more than 100 sections in T.17N., R.112W.; T.18N., R.111-113W.; T.19N., R.111-113W.; and T.20N., R.111-112W. Amoco estimates that each optional well could recover an additional 2.2 to 4.0 billion cubic feet of gas.

In regard to coalbed methane, Quintana Petroleum recently staked five locations to test the Fort Union Formation less than two miles south of the Wyoming-Colorado border and about four miles southeast of Baggs, Wyoming. The tests are in West Side Canal Field which extends into southern Wyoming. Meridian Oil also drilled two tests for coalbed methane in the Fort Union a few miles west of the Quintana locations. No details are available yet on the Meridian wells.

In Sweetwater County, Wyoming, Triton Oil an Gas announced plans to drill a 4,000-foot test for coalbed methane from the Mesaverde Group in NW NW section 33, T.23N., R.102W. Triton already drilled two other tests to the Mesaverde in SW SW section 9, T.22N., R.102W. and in C SW section 1, T.22N., R.102W. Buttonwood Petroleum drilled a 4,200-foot test of the Almond Formation in C NW section 32, T.23N., R.102W. There are still no details on these three wells.

The proposed Kern River Pipeline moved a step closer to fruition when a law judge for the California Public Utilities Commission (CPUC) gave it a favorable recommendation. In the decision, the law judge also endorsed the expansion of Southern California Gas Company's existing pipeline. One of the key points in the law judge's recommendation was that the Kern River project would diversify California's sources of gas supply. The Kern River Pipeline is designed to move large volumes of gas from southwestern Wyoming to California. The full CPUC, however, has still not chosen any particular pipeline to support. Their decision is expected sometime in January.

While estimates of Wyoming's proved reserves of natural gas and natural gas liquids both increased in 1988, an estimate of its proved crude oil reserves declined (Energy Information Administration, 1989). Although the Energy Information Administration's (EIA's) estimates of Wyoming's reserves of crude oil have only declined 3.1 percent since 1979 (Table 3), they have declined 14.3 percent in the last three years. If there had not been a drilling boom in the early 1980s, EIA's estimates of Wyoming's reserves of crude oil would be considerably smaller.

The good news is that EIA's estimates of Wyoming's proved reserves of natural gas and natural gas liquids increased substantially from 1987 to 1988. Estimated reserves of natural gas liquids are over 15 times greater than in 1979 and increased by 16.3 percent between 1987 and 1988. Estimated reserves of natural gas are 39.1 percent higher than in 1979, are 3.1% higher than in 1987, and are only 2.9% lower than the all-time high estimated in 1985. The 1988 increase in proven gas reserves, despite relatively few gas well completions and record gas production in 1988, indicates that Wyoming still has tremendous undeveloped resources of natural gas. These revised estimates are also now reflected in Table 4.

Lease sales did fairly well this year. Total revenue from State and U.S. Bureau of Land Management (BLM) sales exceeded the totals for 1987, but were down from 1988 (Table 5). The high per-acre bid at the October BLM sale was $3,000 by Anderman Oils Ltd. for a 38.61-acre lease in section 24, T.24N., R.112W. The tract offsets a Dakota gas and condensate producer in Lincoln Road Field. Fourteen tracts in the sale received per-acre bids of $100 or more: eight in the Powder River Basin, five in the Greater Green River Basin, and one in the Wind River Basin.

The high per-acre bid in the BLM's December sale was $340 by High Plains Energy Co. for a 41.04-acre parcel in section 4, T.45N., R.71W. The tract is less than one mile west of Muddy Sandstone oil production in Hilight Field and is just east of

Table 3. WYOMING'S PROVED RESERVES OF OIL, NATURAL GAS LIQUIDS, AND NATURAL GAS (1979-1988).

Year	Crude oil [1]	Natural gas liquids[1]	Natural gas[2]
1979	841	53	7.834
1980	928	341	9.413
1981	840	384	9.659
1982	856	476	10.155
1983	957	568	10.728
1984	954	602	11.014
1985	951	664	11.229
1986	849	722	10.393
1987	854	692	10.572
1988	815	805[3]	10.903

Table modified from Energy Information Admininstration, 1989 and Interstate Oil Compact Commission, 1988.

[1] Millions of barrels
[2] Trillions of cubic feet
[3] Estimated by author

Table 4. MINERAL RESOURCE AND RESERVE BASE ESTIMATES FOR WYOMING

PETROLEUM

Remaining Resources (January 1, 1989)	
Discovered (Includes 10 billion barrels recoverable by enhanced recovery techniques)	12.9 billion barrels[1]
Undiscovered	7.6 billion barrels[1]
Total	20.5 billion barrels
Remaining Reserve Base (January 1, 1989)	
Measured reserves (Proved reserves) (Includes 0.815 billion barrels of oil and 0.805 billion barrels of gas liquids)	1.62 billion barrels[2]
Indicated and Inferred reserves	2.8 billion barrels[1]
Total	4.42 billion barrels

NATURAL GAS

Remaining Resources (January 1, 1989)	
Discovered (Includes 23 trillion cubic feet (TCF) of methane[1] and 12 TCF of CO_2 and He[3])	35.0 trillion cubic feet
Undiscovered (Includes 58 TCF of conventional methane[1]; 7 TCF of coalbed methane[4]; 3,611 TCF of methane in tight gas sands in the Green River Basin[5]; and 103 TCF of CO_2 and He[3])	3,779.0 trillion cubic feet
Total	3,814.0 trillion cubic feet
Remaining Reserve Base (January 1, 1989)	
Measured reserves (Proved reserves) (Includes 10.9 TCF of methane[2] and 11.8 TCF of CO_2 and He[3])	22.7 trillion cubic feet

COAL

Remaining Resources (January 1, 1989)	
Identified and Hypothetical (Discovered)	1,431.4 billion tons[6]
Speculative (Undiscovered)	31.5 billion tons[6]
Total	1,462.9 billion tons
Remaining Reserve Base (January 1, 1989)	
Demonstrated strippable (Measured and indicated reserve base)	26.8 billion tons[7]
Demonstrated underground-minable (Measured and indicated reserve base)	38.3 billion tons[7]
Total	65.1 billion tons

TRONA

Original Resources (1983 estimate)	
Trona	81.7 billion tons[8]
Mixed trona and halite	52.7 billion tons[8]
Total	134.4 billion tons

URANIUM

Remaining Resource (December 31, 1985)	1.99 billion pounds U_3O_8[9]
Remaining Reserve Base (December 31, 1985)	
Uranium oxide recoverable at $30.00 per pound	83 million pounds[9]

OIL SHALE

Original Resources (January 1, 1983)	
Identified (Discovered)	320 billion barrels of shale oil[10]

1 Modified from Barlow, J.A., Jr. and Doelger, M.J., 1983, Wyoming mineral resources: Barlow and Haun, Inc., Casper, 14 p.

2 Modified from Energy Information Administration, 1989, U.S. crude oil, natural gas, and natural gas liquids reserves: 1988 Annual Report, October.

3 Derived from Exxon information.

4 DeBruin, R.H., and Jones, R.W., 1989, Coalbed methane in Wyoming: Wyoming Geological Association 40th Annual Field Conference Guidebook, Casper, Wyoming, p. 97-103.

5 Law, B.E., and others, 1989, Estimates of gas resources in overpressured low-permeability Cretaceous and Tertiary sandstone reservoirs, Greater Green River Basin, Wyoming, Colorado, and Utah: Wyoming Geological Association, 40th Annual Field Conference Guidebook, Casper, Wyoming p. 39-61.

6 Wood, G.H., Jr. and Bour W.V., III, 1988, Coal map of North America: U.S. Geological Survey Special Geologic Map, 1:5,000,000 scale (color) and 44 p. pamphlet.

7 Geological Survey of Wyoming, April, 1989. (Modified from Berryhill, H.L., Jr. and others, 1950), Coal resources of Wyoming: U.S. Geological Survey Circular 81, 78 p.

8 Culbertson, W.C., 1983, Genesis and distribution of trona deposits in Wyoming (abstract) in Genesis and exploration of metallic and nonmetallic mineral and ore deposits of Wyoming and adjacent areas: Geological Survey of Wyoming Public Information Circular 19, p.34.

9 Energy Information Administration, 1985, Uranium industry annual: U.S. Department of Energy Report DOE/EIA-0478(85) 142 p.

10 Knutson, C.F., and Dana, G.F., 1982, Developments in oil shale in 1981: American Association of Petroleum Geologists . Bulletin, Volume 66, no. 11, p. 2513.

Table 5. FEDERAL AND STATE COMPETITIVE OIL AND GAS LEASE SALES IN WYOMING

BLM SALES

Month	Total Revenue	Number of parcels offered	Number of parcels leased	Total acres	Acres leased	Average price per acre leased	High price per acre
			1987				
TOTAL	$15,724,159	727	646	197,422	177,960	$ 88.36	$6,555.00
			1988				
March	$7,338,210	866	336	1,073,940	315,387	$23.27	$525.00
June	$7,564,135	820	375	755,242	293,050	$25.81	$575.00
August	$5,827,548	847	363	827,471	278,198	$20.95	$1,350.00
October	$3,913,765	820	257	994,618	282,145	$13.87	$6,500.00
December	$3,045,203	766	260	761,242	182,117	$16.72	$330.00
TOTAL	$27,688,861	4,119	1,591	4,412,513	1,350,897	$20.50	$6,500.00
			1989				
February	$2,418,295	800	230	857,475	187,012	$12.93	$1,225.00
April	$2,334,604	732	227	557,643	145,055	$16.09	$390.00
June	$1,673,150	758	163	962,929	138,691	$12.06	$160.00
August	$3,469,570	656	197	577,518	141,841	$24.46	$285.00
October	$3,247,334	788	296	657,918	178,013	$18.24	$3,000.00
December	$2,689,152	552	247	415,266	181,791	$14.79	$340.00
TOTAL	$15,832,105	4,286	1,360	4,028,750	972,403	$16.28	$3,000.00

STATE SALES

Month	Total Revenue	Number of parcels offered	Number of parcels leased	Total acres	Acres leased	Average price per acre leased	High price per acre
			1987				
TOTAL	$2,526,567	1,200	579	511,638	244,740	$10.32	$2,300.00
			1988				
January	$826,698	200	142	76,953	56,430	$14.65	$200.00
March	$800,213	200	133	76,304	48,423	$16.53	$465.00
May	$1,649,974	200	182	75,987	69,285	$23.81	$290.00
July	$1,855,646	200	155	77,168	60,519	$30.66	$375.00
September	$751,646	200	142	68,456	55,168	$13.63	$180.00
November	$318,547	200	119	71,085	42,118	$7.56	$130.00
TOTAL	$6,202,724	1,200	873	445,953	331,943	$18.69	$1,640.00
			1989				
January	$331,145	200	112	73,322	39,650	$8.35	$110.00
March	$493,179	200	129	74,512	47,886	$10.30	$140.00
May	$512,736	199	129	76,396	51,919	$9.88	$155.00
July	$684,374	200	154	82,760	65,034	$10.52	$190.00
September	$474,104	200	134	77,889	50,749	$9.34	$540.00
November	$628,446	200	134	76,973	56,036	$11.22	$170.00
TOTAL	$3,123,984	1,199	792	461,852	311,274	$10.04	$540.00

Sources: Wyoming Department of Public Lands, Petroleum Information Corporation - Rocky Mountain Region Report, and U.S. Bureau of Land Management.

a Minnelusa test being drilled by NICOR Exploration. Eight parcels in this sale received per-acre bids of $100 or more. Four were in the Powder River Basin, one in the Bighorn Basin, one in the Wind River Basin, and two in the Green River Basin.

Two parcels received the high bid at the Wyoming Department of Public Land's November sale. Paul Sawyer paid $170 per acre for a 320-acre lease which included SE section 33 and SW section 34, T.54N., R.68W. The lease is less than a mile southwest of Minnelusa oil production in Lily Field. Brown Operating also paid $170 per acre for a 40-acre tract which contained NW NW section 33, T.50N., R.71W. The lease is one mile east of Minnelusa oil production in AG Farm Field. No other tracts got bids of $100 or more per acre.

Figure 4 and Tables 6 and 7 are included in this issue of *Wyoming Geo-notes* to update earlier versions of the same figure and tables. These illustrations now include 1988 data.

Based on company data and on information compiled and published by Petroleum Information, the following significant exploration and development events occurred in Wyoming during the fourth quarter of 1989. The letters preceding the following discussions refer to the locations on Figure 5:

A. Texaco Inc. is drilling a 16,000-foot Frontier and Dakota test in SE NE section 13, T.12N., R.116W. The well is about four miles northwest of Dakota oil production at Graham Reservoir Field.

B. Wexpro Co. has completed three more prolific gas wells in Church Buttes Field. Wexpro is in partnership with Union Pacific Resources in the development of this field. The 58 Church Buttes Unit well, completed in SW SE section 12, T.17N., R.112W., flowed 1.17 million cubic feet of gas and 15 barrels of water per day from the Frontier Formation; the 60 Church Buttes Unit well in N/2 NE section 23, T.17N., R.112W. was completed for 789,000 cubic feet of gas and five barrels of condensate per day in the Dakota; and the 56 Church Buttes Unit well flowed 1.18 million cubic feet of gas and 22 barrels of water per day from the Frontier in C NW section 16, T.17N., R.112W.

C. Lincoln Road Field has another good Dakota well. Thermal Exploration's 2-22 Lincoln Road well in NW NE section 22, T.24N., R.111W. flowed 692,000 cubic feet of gas, 214 barrels of 54.4° API gravity condensate, and nine barrels of water per day.

D. Wold Oil and Gas completed a shallow pool discovery in Longs Creek Field, an abandoned Phosphoria field. The discovery well, the 3 Government-Hearney in NW NE section 5, T.31N., R.94W., flowed 346,000 cubic feet of gas per day from the Frontier Formation.

E. Amoco Production completed an 18,900-foot wildcat to the Morrison as a Lakota gas discovery. The 1 Frewen Deep Unit well was drilled in NE SE section 13, T.19N., R.95W. No details have been released except that the well will be shut

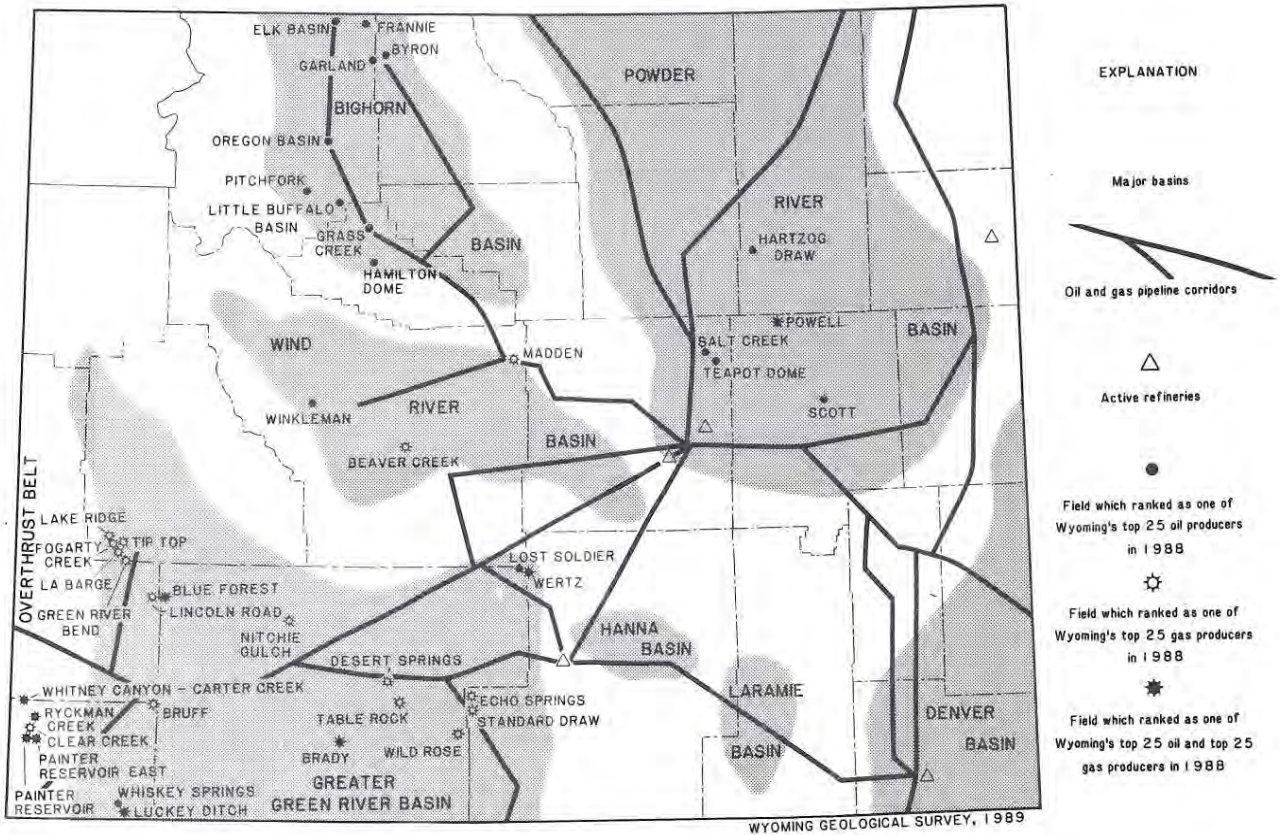

Figure 4. GENERALIZED OIL AND GAS INDEX MAP OF WYOMING.

Table 6. TOP 25 OIL FIELDS IN WYOMING BASED ON 1988 PRODUCTION (WYOMING OIL AND GAS CONSERVATION COMMISSION, 1989).

Name	Year discovered	1988 Production (barrels)	Cumulative production through 1988 (barrels)
Oregon Basin	1912	8,567,827	387,764,975
Hartzog Draw	1976	6,311,431	66,130,730
Salt Creek	1889	5,054,571	626,535,345
Wertz	1921	3,741,716	99,585,418
Painter Reservoir East[1]	1987	3,461,626	6,953,041
Elk Basin	1915	2,856,266	431,865,966
Hamilton Dome	1918	2,801,389	230,131,213
Little Buffalo Basin	1914	2,667,937	118,442,471
Garland	1906	2,647,416	162,763,914
Grass Creek	1914	2,435,610	184,922,836
Brady	1973	2,245,287	55,228,028
Pitchfork	1930	1,991,528	35,069,079
Luckey Ditch	1985	1,791,610	3,911,374
Lost Soldier	1916	1,717,013	209,424,472
Whitney Canyon-Carter Creek	1978	1,692,168	9,072,637
Powell	1954	1,691,067	18,595,232
Painter Reservoir[1]	1977	1,585,306	44,639,081
Winkleman	1917	1,094,166	86,463,795
Byron	1918	1,052,125	120,444,042
Frannie	1928	1,038,995	112,211,259
Ryckman Creek	1976	996,156	17,107,885
Teapot Dome Naval Reserve	1922	923,095	20,084,111
Scott	1979	827,536	11,604,296
Whiskey Springs	1987	782,771	930,937
Blue Forest	1983	737,655	775,504
		60,712,267	3,060,657,641

[1] Before 1987, production for Painter Reservoir and Painter Reservoir East Fields was combined under Painter Reservoir.

Table 7. TOP 25 GAS FIELDS IN WYOMING BASED ON 1988 PRODUCTION (WYOMING OIL AND GAS COMMISSION, 1989)

Name	Year discovered	1988 Production (MCF)[1]	Cumulative production through 1988 (MCF)[1]
Whitney Canyon-Carter Creek	1978	104,535,316	596,049,591
Fogarty Creek[2]	1976	103,716,041	263,868,649
Lake Ridge[2]	1981	46,705,579	103,971,766
Painter Reservoir[3]	1977	36,010,715	354,972,853
La Barge	1925	27,281,783	270,611,348
Painter Reservoir East[3]	1987	24,833,396	48,968,370
Brady	1973	23,342,710	286,385,018
Ryckman Creek	1976	21,446,070	124,061,805
Wertz[4]	1921	20,780,066	48,029,936
Table Rock	1946	18,181,728	432,691,117
Bruff	1974	18,115,423	121,388,806
Blue Forest	1983	17,876,487	18,780,603
Powell	1954	17,577,969	95,485,462
Clear Creek	1979	16,531,951	104,861,672
Madden	1969	15,185,652	268,378,831
Echo Springs	1976	14,109,120	143,169,299
Lincoln Road	1977	11,755,876	24,131,098
Standard Draw	1979	11,480,198	99,851,156
Tip Top	1928	8,947,239	336,279,338
Green River Bend	1958	8,133,523	188,140,413
Beaver Creek	1938	7,944,463	561,315,605
Desert Springs	1958	7,604,884	254,843,574
Luckey Ditch	1985	7,604,373	17,476,445
Nitchie Gulch	1962	6,892,831	88,707,948
Wild Rose	1975	6,777,801	75,280,785
		603,371,194[5]	4,927,701,488[6]

[1] Thousand cubic feet.
[2] Approximately two-thirds of the production from this field is carbon dioxide.
[3] Before 1987, production from Painter Reservoir and Painter Reservoir East Fields was combined under Painter Reservoir.
[4] Nearly all gas production from Wertz is carbon dioxide derived from tertiary operations and the carbon dioxide is recycled.
[5] Approximately 100,000,000 MCF are carbon dioxide.
[6] Approximately 245,000,000 MCF are carbon dioxide.

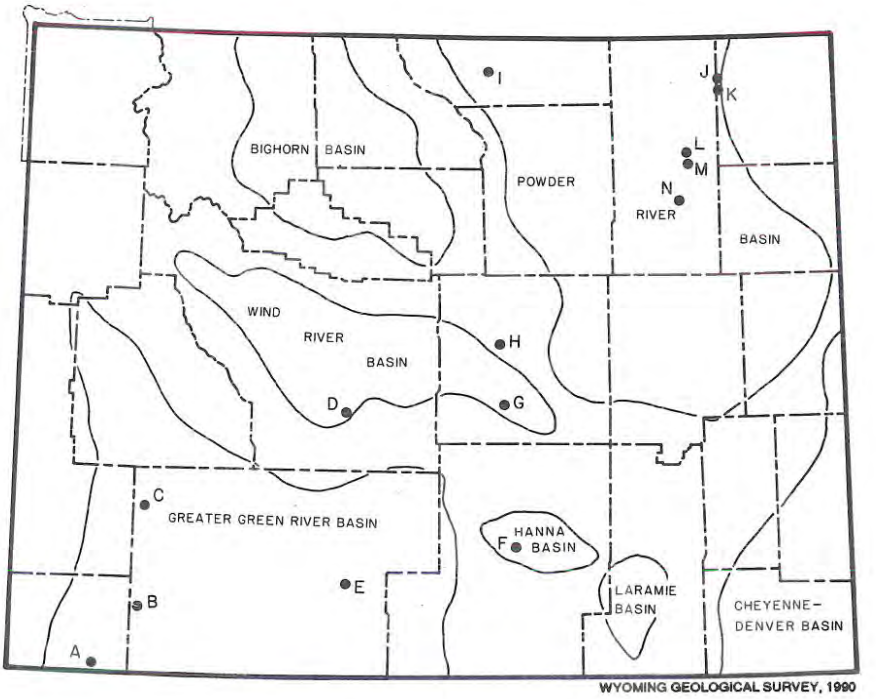

Figure 5. OIL AND GAS EXPLORATION AND DEVELOPMENT ACTIVITY IN WYOMING.

in until a pipeline connection is made. Amoco has plans to drill two more deep tests in the area.

F. Sullivan and Co. plans to drill a 16,500-foot Tensleep test in NW SW section 12, T.22N., R.85W. in the Hanna Basin. The well is planned for the first quarter of 1990. Primary objectives of the well are the Sundance and Tensleep.

G. Austin Creek Field has a new Muddy Sandstone producer. The 1-12 Van Irvine Trust well in SE NE section 12, T.32N., R.85W. flowed 303 barrels of oil and 416,000 cubic feet of gas per day. Amoco acquired the Austin Creek properties when it bought Tenneco's Rocky Mountain Division last year. This is the third producing well in the field, which was discovered in 1988.

H. Notches Field, discovered in 1923, underwent a $4.8 million development program during late 1988 and early 1989. Pacific Enterprises Oil Co. drilled thirteen new wells and 10 were completed as new Tensleep Sandstone producers. The program extended the field to the south and west. Through the first nine months of

1989, production at the field, which is in T.37N., R.85W., stood at 426,065 barrels of oil. Production for all of 1988 was only 203,060 barrels of oil. This field provides a good indication of how much oil remains in some of Wyoming's older fields.

I. True Oil is drilling a 12,500-foot Minnelusa test on the western flank of the Powder River Basin in NW SE section 14, T.55N., R.83W. Arvada Field, 35 miles to the southeast, is a shut-in Minnelusa field.

J. Lario Oil and Gas pumped 172 barrels of oil during a 24-hour production test of the Minnelusa at their 11 Shepherd well in SW SW section 17, T.54N., R.67W.

K. Chaparral Resources discovered oil in the Minnelusa at their 1-A J.B. Hahn well in SE NW section 20, T.53N., R.68W. The initial pumping potential was 69.5 barrels of oil per day. The well was drilled about 100 feet north of the abandoned J B Field discovery. That discovery well produced 13,104 barrels of oil before its abandonment.

L. Lasmo Energy has discovered Superhornet Field in the Minnelusa and has drilled two successful development wells. The discovery well, the 1-15 Superhornet in NE SE section 15, T.50N., R.71W., averaged 531 barrels of oil per day during 26 days of production in September. The company also completed the 2-15 Superhornet in SW NE section 15, T.50N., R.71W. pumping 328 barrels of oil and 193 barrels of water per day. The 3-15 Superhornet in NE NW section 15, T.50N., R.71W. was completed pumping 768 barrels of oil per day.

M. Ampolex, Inc. completed their third Minnelusa well in W D Field. The 24-34 Federal in SE SW section 34, T.49W., R.71W. pumped 290 barrels of oil per day. Between August and its discovery in June, W D Field produced 20,423 barrels of oil.

N. Lasmo Energy has an apparent discovery in the Minnelusa. The 1-30 Appaloosa well in SW SW section 30, T.45N., R.72W. recovered 180 feet of 37° API gravity oil, 1,550 feet of gas-cut water-cushion, and 90 feet of gas-cut mud. This well, if economical, would be one of the most southerly producers in the Minnelusa trend of the Powder River Basin.

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COAL UPDATE

by Richard W. Jones, Coal Division Head, Geological Survey of Wyoming

Production indicators during the last quarter of 1989 continued to show Wyoming's 1989 coal production substantially ahead of 1988's record production. Through September, reported coal deliveries from mines in Wyoming were about 7.8 million tons ahead of deliveries for the same period in 1988 (see Table 8 and Figure 6). The Energy Information Administration (1989) estimated that production from Wyoming mines through November, 1989 was about 3.2 million tons ahead of production reported for the same period in 1988. Projecting these two estimates to the end of 1989 (assuming that the average monthly production does not change) yields final coal production between 166 and 171 million tons. These estimates are consistent with the 170 million tons we predicted in late 1989 *(Wyoming Geo-notes* No. 24, October, 1989, p. 11).

As was noted in the 24th issue of *Wyoming Geo-notes*, increased sales of coal on the spot market are apparently accounting for much of the increase in coal production in 1989. In the first eight months of 1988, 4.9 million tons of spot sales accounted for about 4.8 percent of total reported coal deliveries. By comparison, spot sales for the same period in 1989 totalled 9.1 million tons or 8.3 percent of all reported deliveries. In July and August of 1989, spot sales accounted for over 10 percent of the total coal deliveries. Our production forecast for 1989-1995 (see Table 9) remains unchanged from that made in October, 1989. Figure 6, incidentally, shows that significant production gains occurred in five of the first six months of 1989.

Projects to upgrade Wyoming coal were back in the news in the fourth quarter of 1989. In late December, the U.S. Department of Energy (DOE) selected Encoal Corporation, a wholly-owned subsidiary of Shell Mining Company (owned by Shell Oil Company), as the recipient of $36 million in Federal funds from round three of DOE's Clean Coal Technology Program. Encoal Corporation's project is a demonstration-sized coal processing plant that will convert 1,000 tons of coal per day to hydrocarbon liquids and upgraded coal. They will use technology that was recently licensed to TEK-KOL Partnership a jointly-owned venture between Shell Mining Company of Houston, Texas, and SGI International of LaJolla, California.

Encoal's plant will be located at Triton Coal Company's Buckskin mine north of Gillette, Wyoming, and will convert 8,300-Btu per pound, low-sulfur, high-moisture-content coal into a liquid similar to No. 6 fuel oil and into an upgraded coal with approximately six percent moisture and a heat value of about 12,000 Btu per pound. Encoal Corporation's plant is the only Wyoming project among the 13 projects selected in the third round of DOE's initiative for clean coal technology. Shell Mining Company will provide $36 million of their own funds to match the Federal funds.

The K-Fuels project apparently progressed another step in late 1989 with the announcement that Smith Powerfuels would construct a $50 million K-Fuel plant near Gillette in 1990. Smith Powerfuels is a partnership between Smith Cogeneration, Incorporated of Oklahoma City, Oklahoma Energy American of San Diego,

Table 8. COAL DELIVERIES BY MONTH FROM WYOMING MINES[1]

	1985 MONTHLY	1985 CUMULATIVE	1986 MONTHLY	1986 CUMULATIVE	1987 MONTHLY	1987 CUMULATIVE	1988 MONTHLY	1988 CUMULATIVE	1989 MONTHLY	1989 CUMULATIVE
JANUARY	11,601,200	11,601,200	11,646,300	11,646,300	12,085,570	12,085,570	10,976,860	10,976,860	14,283,020	14,283,020
FEBRUARY	10,473,900	22,075,100	10,317,700	21,964,000	10,315,680	22,401,250	11,431,380	22,408,240	11,488,140	25,771,160
MARCH	11,674,900	33,750,000	11,401,720	33,365,720	10,436,610	32,837,860	12,871,090	35,279,330	14,124,330	39,895,490
APRIL	11,632,800	45,382,800	9,954,170	43,319,890	10,429,180	43,267,040	12,694,660	47,973,990	13,489,450	53,384,940
MAY	11,497,900	56,880,700	10,105,320	53,425,210	10,619,470	53,886,510	12,017,500	59,991,490	13,149,170	66,534,110
JUNE	11,692,200	68,572,900	10,499,280	63,924,490	11,953,650	65,840,160	12,595,480	72,586,970	12,948,350	79,482,460
JULY	11,893,500	80,466,400	11,497,190	75,421,680	12,850,240	78,690,400	13,905,670	86,492,640	14,043,350	93,525,810
AUGUST	12,107,100	92,573,500	11,773,510	87,195,190	13,460,470	92,150,870	15,041,090	101,533,730	15,428,210	108,954,020
SEPTEMBER	11,325,000	103,898,500	11,474,820	98,670,010	12,651,550	104,802,420	13,433,610	114,967,340	13,795,760	122,749,780
OCTOBER	11,048,500	114,947,000	10,854,670	109,524,680	12,248,080	117,050,500	13,696,190	128,663,530		
NOVEMBER	10,589,700	125,536,700	11,971,990	121,496,670	12,340,720	129,391,220	13,889,890	142,553,420		
DECEMBER	11,459,300	136,996,000	13,025,490	134,522,160	13,008,300	142,399,520	14,540,510	157,093,930		
TOTAL TONNAGE REPORTED	136,996,000		134,522,160		142,399,520		157,093,930			
TOTAL TONNAGE NOT REPORTED	3,784,154		1,782,896		4,089,128		6,494,270			
TOTAL TONNAGE PRODUCED[2]	140,780,154		136,305,056		146,488,648		163,588,200			

[1] Source: National Marketing Reports by Coal Marketronix and COALDAT Marketing Report by DRI, Inc., compiled from FERC Form 423 filed monthly by electric utilities.

[2] Source: Wyoming State Mine Inspector's Annual Reports.

California (an affiliate of Occidental Petroleum), and K-Fuel Partnership of Gillette, Wyoming, and Denver, Colorado. The new plant is evidently a commercial version of the $10 million K-Fuel demonstration plant that has been operating at the Fort Union mine north of Gillette. The new plant will convert two tons of run-of-mine subbituminous coal to one ton of K-Fuel pellets. The pellets are characterized by their low-sulfur, low-ash, low-moisture and high-Btu content. The plant should produce enough pellets to support about a 1,000-megawatt electric-generating plant.

Wisconsin Power and Light Company has agreed, in principle, to purchase all of the plant's output. Although the cost of the fuel pellets is estimated at about $40 a ton F.O.B. the plant, Smith Powerfuels believes the fuel will be in demand from older coal-fired plants (currently burning high-sulfur Eastern coal) that will be required to reduce stack emissions in response to acid rain legislation.

Also, several electric utility companies have recently announced that they will be conducting test burns of Amax Coal Company's dried coal product. Fremont, Nebraska Department of Utilities purchased 1,500 tons of dried coal to test in a 17-megawatt generating unit. If the burn is successful, the Department of Utilities could use from 25,000 to 30,000 tons of the dried coal as a peaking fuel (a higher quality coal added to a boiler to obtain full power to output), particularly in the event that their new coal supply contract is for Powder River Basin coal. The dried coal product shipped to Fremont's Wright generating station had a sulfur content of 0.3 percent, from 10 to 12 percent moisture, and a heating value of about 10,400 Btu per pound. The dried coal reportedly cost $14 a ton F.O.B. Amax's Belle Ayr plant and $24 a ton delivered (McGraw-Hill, Inc., 1989a).

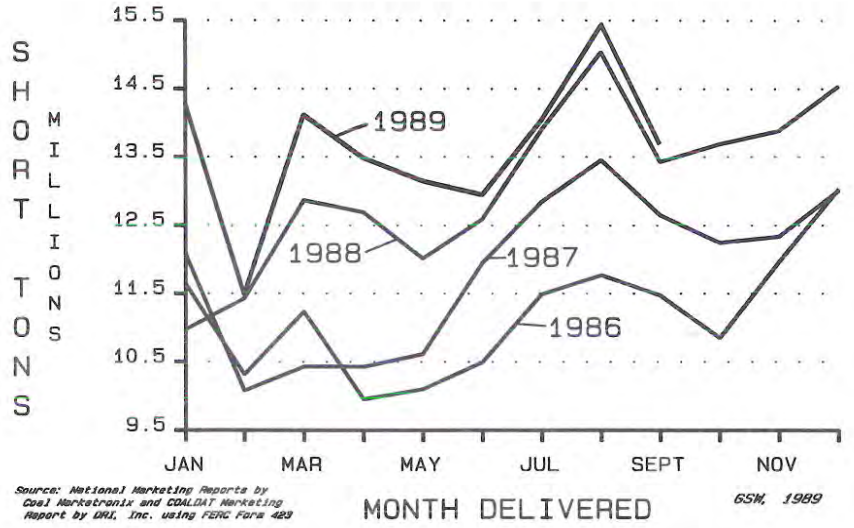

Figure 6. REPORTED DELIVERIES FROM WYOMING COAL MINES.

Table 9. COAL PRODUCTION AND FORECAST TO 1995 (MILLIONS OF TONS).

	1983[1]	1984[1]	1985[1]	1986[1]	1987[1]	1988[1]	1989	1990	1991	1992	1993	1994	1995
Campbell County	88.2	106.8	113.9	111.0	122.3	135.7	143.7	150.9	156.9	161.6	164.8	168.1	171.5
Converse County	2.7	3.3	3.6	4.8	5.1	5.7	5.9	6.0	6.5	7.0	7.5	7.5	7.5
Sheridan County	2.9	2.5	2.4	1.4	1.2	0.9	0.1	M	M	M	M	M	M
Carbon County	4.8	5.1	3.3	1.5	2.2	4.1	3.5	3.0	2.5	2.0	2.0	2.0	2.0
Sweetwater County	9.5	8.9	13.2	12.9	11.8	12.2	11.8	12.0	12.5	13.0	13.0	13.0	13.0
Lincoln County	4.0	4.1	4.3	4.0	3.8	4.9	5.0	5.2	5.4	5.6	5.8	5.8	5.8
Hot Springs County	M	M	M	M	M	M	M	M	M	M	M	M	M
Total Wyoming[3]	112.2	130.7	140.7	135.7	146.5	163.6	170.0	177.1	183.8	189.2	193.1	196.4	199.8
Annual change	4%	16.5%	7.7%	-3.6%	8.0%	11.7%	3.9%	4.2%	3.8%	2.9%	2.1%	1.7%	1.7%
Estimated contracted production	122.6	137.7	145.2	149.2	150.0	154.9	160.0	165.0	170.0	175.0	180.0	185.0	190.0

[1] These are actual values for comparison. [2] M means minor tonnage (less than 0.1 million tons). Forecast by Geological Survey of Wyoming, October, 1989. [3] Totals may not equal sum of components because of independent rounding.

Iowa Public Service Company announced in October that they would also conduct a test burn of Amax's dried coal product at their George Neal No. 3 generating plant when the product becomes available.

Developments in the Hanna Coal Field

Perhaps the biggest news in the Hanna Coal Field was Arch of Wyoming's announcement that the State's legislated tax breaks of past years had paid off at least for Arch. In 1989 the company employed 40 more people than in 1988 and production was expected to be about 1.2 million tons greater than in 1988, or 3.0 million tons. They anticipated hiring another 13 people late in 1989 or in early 1990. In fact, a company spokesman felt they were doing well enough that they were not even planning to ask the Legislature to extend the tax exemption that expires in 1991.

Developments in western and southwestern Wyoming

As a follow-up to the article about Arch Mineral Corporation's purchase of the Stansbury mine north of Rock Springs (see *Wyoming Geo-notes* No. 24, October, 1989, p. 18), Arch announced in November that they were hiring 35 to 40 persons to work at the mine in anticipation of a January, 1990 startup date. Production of bituminous coal from the underground mine, now called the Pilot Butte mine, will be sold to Pacific Power and Light Company's (PP&L) Jim Bridger power plant east of Rock Springs. Although no firm contract has been signed, the two companies verbally agreed on coal shipments of 25,000 to 30,000 tons per month to the power plant. The coal will be hauled from the mine to the plant by trucks.

In southwestern Wyoming, transporting coal by truck is gaining in popularity. Savage Industries currently hauls about one million tons of coal annually from the Black Butte coal mine to PP&L's Jim Bridger plant; coal from the Pilot Butte mine will be hauled by truck (see previous paragraph); and most recently, Pittsburg and Midway Coal Mining Company (P&M) and Bonneville Transloaders, Incorporated (BTI) signed a coal transportation contract. The new contract calls for BTI to transport 500,000 tons of coal per year from P&M's Kemmerer mine to General Chemical Company's trona processing plant west of Green River. The coal will be transported by 40-ton trucks from a $1.7 million truck loadout facility (to be constructed by P&M at Kemmerer) south on U.S. Highway 30 to Granger, and then east on U.S. Interstate Highway 80 to General Chemical's plant. BTI already does extensive hauling of soda ash for the trona industry in southwestern Wyoming, but the new contract is the company's first coal haulage contract. The coal from P&M's Kemmerer mine was previously transported to General Chemical by Union Pacific Railroad (UP).

Developments in the Powder River Basin Coal Field

The National Coal Association recently released a report that listed the top 10 coal-producing mines for 1988. Six of the top seven coal mines in the United States in 1988 were from Campbell County and the Powder River Basin, Wyoming. At the top of the list for the fifth consecutive year was Thunder Basin Coal Company's Black

Thunder mine, which produced 24.9 million tons in 1988. Kerr-McGee Coal Corporation's Jacobs Ranch mine was third, followed by Cordero Mining Company's Cordero mine, Amax Coal Company's Belle Ayr and Eagle Butte mines, and Carter Mining Company's Caballo mine. Two other mines in the Montana portion of the Powder River Basin, Western Energy Company's Rosebud mine and Decker Coal Company's Decker mine, ranked second and tenth, respectively. Lignite mines in Texas and North Dakota were also listed among the top ten coal mines.

The Black Thunder mine received additional distinction in October as it became the first coal mine in North America to produce and ship its 200 millionth ton of coal. After opening in 1977, the first 100 million tons were produced and shipped by July, 1985; the 200 millionth ton was shipped on October 24, 1989. Amax Coal Company's Belle Ayr mine reached the 200-million-ton milestone in December 1989. The Belle Ayr mine also was the first mine in the United States to reach both the 100 millionth and the 150 millionth ton milestones.

There was another milestone reached in 1989. Coal from the Powder River Basin of Wyoming was burned in Kentucky, formerly the leading coal-producing state in the United States and currently the leading eastern coal-producing state. In October, Kentucky Utilities Company (KUC), the State's largest electric utility, tested 10,000 tons of coal from the Cordero mine south of Gillette, Wyoming.

Evidently KUC wanted to see if Wyoming coal was a viable option to help it comply with anticipated acid rain legislation that will raise the clean air standards. It is expected that acid rain legislation will allow utility companies to meet increased stack emission standards by either burning lower sulfur coal or by installing scrubbers and other antipollution equipment. The Wyoming coal was the first western coal ever used by Kentucky Utilities Company. The test burn was reportedly a success and created no operational or technical problems at KUC's Ghent power plant.

Coal contracts - Powder River Basin

A December solicitation by the Lower Colorado River Authority (LCRA) for spot coal to fuel Fayette Units 1, 2, and 3 resulted in F.O.B. mine bids that ranged from a low of $3.80 a ton, submitted by Cordero Mining Company (a subsidiary of Sun Coal Company) to a high of $5.10 a ton submitted by Peabody Development Company, owner of the Rochelle mine. A September solicitation by San Antonio City Public Service Company brought F.O.B. mine bids that ranged from $3.54 a ton, submitted by Sun Coal Company, to $5.00 a ton from both the Rochelle mine and the Black Thunder mine. In both these solicitations, the low bids in dollars per ton were also the lowest bids in cents per million Btu's.

Triton Coal Company's Buckskin mine recently lost some contracted coal tonnage when two utility companies decided to reduce their coal shipments. Western Farmers Electric Cooperative plans to reduce their burn of coal from 1.5 to 1.1 million tons in 1990 and make up the difference by burning natural gas, which is evidently comparable in price (at the busbar) to coal. Grand River Dam Authority

(GRDA) ended deliveries of a maximum of 400,000 tons of coal from the Buckskin mine after accepting delivery of only 200,000 tons. GRDA apparently had too much coal stockpiled and in transit to need the additional coal.

In November, Kerr-McGee Coal Corporation was awarded a 5- to 7-year, 4.5-million-ton contract to supply Indiana-Michigan Power Company's Rockport 2 generating plant. This may be part of the additional 2 million tons of coal per year that the utility was seeking earlier (see related story in *Wyoming Geo-notes* No. 24, October, 1989, p. 19). The coal will be mined at Kerr-McGee's Jacobs Ranch mine, transported by Burlington Northern Railroad (BN) to the Ohio River, and transferred to barge for delivery to Rockport No. 2. The 8,600-Btu per pound coal reportedly sold for a price between $4.00 and $4.50 a ton F.O.B. the mine.

Cordero Mining Company's Cordero mine will supply 120,000 tons of spot coal to LCRA's Fayette Units 1 and 2 near Austin, Texas. This is half of the 239,400 tons that LCRA originally solicited (see *Wyoming Geo-notes* No. 24, October, 1989, p. 20, item no. 1); the $3.50 a ton (F.O.B. the mine) price in the original solicitation was retained through a later solicitation that called for half the original tonnage.

Thunder Basin Coal Company (a subsidiary of Arco Coal Company) and Nebraska Public Power District (NPPD) recently completed amendments to a coal supply contract for the Gentleman, Nebraska generating station and signed a new agreement to supply coal to the Sheldon, Nebraska generating station. The price of coal from the Black Thunder mine to the Gentleman station was reduced from an earlier price. Because the new contract was retroactive to July 1, 1988, NPPD will receive a $5 million refund on previously purchased coal. The contract will continue at 2.7 million tons per year through 1996. The new contract to supply NPPD's Sheldon plant calls for extending the current one-year, 500,000-ton per year agreement through 1996. These new coal supply agreements are expected to save NPPD's customers about $57 million over the next 6 years.

Carter Mining Company's Caballo mine will supply 400,000 tons of spot coal to Iowa Public Service Company's George Neal No. 4 generating unit. Deliveries via Chicago and North Western Transportation Company began in September, 1989. Carter Mining also supplies this plant with about 2.0 million tons per year of contract coal.

Amax Coal Company has contracted with Omaha Public Power District to supply 1.1 million tons of coal from their Belle Ayr mine to the utility's North Omaha, Nebraska generating plant. Deliveries of the coal via Burlington Northern began in mid-November and will continue through the summer of 1990.

Rochelle Coal Company (through Peabody Development Company), Amax Coal Company, and Mobil Coal Producing, Incorporated have each signed coal supply contracts for 1990 with Pacific Power and Light Company. They will supply supplemental coal to the Dave Johnston power plant at Glenrock, Wyoming and possibly to the Jim Bridger power plant east of Rock Springs and to the Centralia, Washington power plant. Rochelle Coal Company will supply between 400,000 and

800,000 tons of coal from their Rochelle mine; Amax will supply between 200,000 and 400,000 tons of coal from their Belle Ayr mine; and Mobil will supply between 200,000 and 400,000 tons from their Caballo Rojo mine. The supplemental coal purchases are part of PP&L's continuing efforts to reduce power costs, to enhance boiler performance, and to extend the life of company-owned mines near the power plants (McGraw-Hill, 1989b).

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INDUSTRIAL MINERALS UPDATE

by Ray E. Harris, Industrial Minerals and Uranium Division Head, Geological Survey of Wyoming

Aggregate (Construction)

The production of construction aggregate (sand and gravel, crushed rock, and railroad ballast), which probably increased in 1989, is also expected to increase in coming years. The railroad ballast quarry west of Cheyenne at Granite, Wyoming, is expanding, and increasing annual production. In 1987, Meridian Minerals, a division of Burlington Northern, Inc., purchased this quarry from Morrison-Knudsen. Meridian sells ballast to both the Union Pacific and Burlington Northern Railroads. Burlington Northern, in agreement with Union Pacific, now has trackage rights to the quarry.

Although the production of construction aggregate declined during the last quarter of 1989 due to the weather, stockpiled fine aggregate is used on highways through the winter to increase traction on ice and snow. Production of aggregate should begin increasing again in the spring of 1990, particularly as highway construction projects resume.

Rissler & McMurry, a Casper-based construction company, has proposed construction of a new limestone aggregate quarry on the north side of Bessemer Mountain west of Casper. Local residents, however, are protesting the quarry's location.

Bentonite

Bentonite is a clay product that has many uses. It swells many times its dry volume when wet and has a high cation exchange capacity. Because of its sealing properties, it is the primary ingredient in oil and gas well drilling fluids, it is used to line settling ponds, and it is desirable for certain construction applications. It is also used in iron ore refining, foundry casting, soap, cosmetics, and as a mineral filler in many products.

In the value of its production, bentonite is Wyoming's second most important industrial mineral (after mined trona). The major producing areas are the Colony area in the northern Black Hills, the Clay Spur area in the southern Black Hills, the eastern Bighorn Basin, the Kaycee area, and near Casper (see Figure 7). Wyoming is still the Nation's largest producer of bentonite.

Since the main use of bentonite is for drilling muds, the decline in domestic oil and gas exploration has depressed the bentonite industry. However, because other uses of bentonite are increasing, bentonite production in Wyoming is increasing slowly.

Wyo-Ben, a bentonite mining company, has apparently been granted its application to expand its mining area near Greybull, in Big Horn County. To settle landowner protests, the company agreed to withdraw the ten percent of the acreage in the original permit that was adjacent to the landowners' properties.

Cement

In Laramie, cement production at Wyoming's only cement plant reached full production in 1989 for the first time following the major renovation begun in 1987. The renovation, which modernized Mountain Cement's plant and enlarged its capacity, also changed the production system from a wet process to a dry process. This plant is providing Portland cement to construction projects in Colorado, Nebraska, and Wyoming.

Gypsum

Gypsum is produced in Wyoming at two localities in the Bighorn Basin where it is used for wallboard and at one locality near Laramie where it is used in the manufacture of cement (see previous section on Cement). The production of wallboard by Celotex Corp. in Cody, and by Georgia-Pacific, south of Lovell, remained relatively constant or increased slightly in 1989. The production of gypsum by Mountain Cement near Laramie is keeping pace with the increased production of cement.

Mountain Cement opened a new gypsum quarry about eight miles south of Laramie. In the early 1900s, gypsum was mined in this area for use in a plaster plant located on the site. If this quarry produces suitable gypsum, it should result in

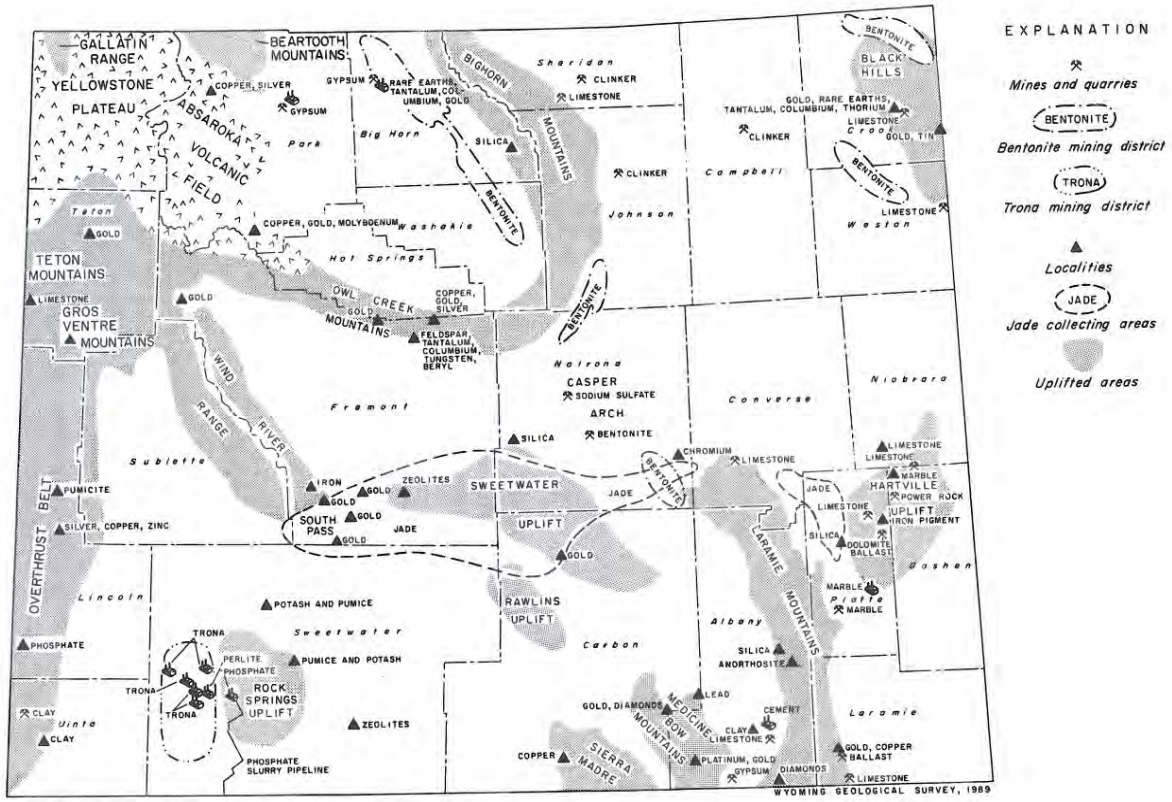

Figure 7. SELECTED MINERAL AND ROCK OCCURRENCES.

considerable savings for Mountain Cement since the company was hauling gypsum 40 miles from the Red Mountain quarry southwest of Laramie.

Limestone

Limestone is quarried in Wyoming for construction aggregate (particularly highway base, sub-base, and surfacing), for cement, and for use in emissions control at coal-fired power plants. Wyoming has been exporting crushed limestone from near Hartville to the State of Nebraska for use as aggregate for road construction. In the past, limestone has been produced in Wyoming as dimension stone and as "sugar rock" for use in refining sugar beets.

Because limestone production in Wyoming is now heavily dependent on road construction, production decreased in November and December, 1989 with the seasonal slowdown in construction. Limestone production in 1990 should increase slightly over 1989 production. For the longer term, production of limestone is also expected to increase, especially if new markets are established in adjacent states.

Lime is a product made from limestone. Although lime (CaO) is made in Wyoming, it is not produced for commercial sale. In Laramie, Mountain Cement manufactures lime for their cement plant. However, lime produced for cement is consumed in the final product. Lime is also produced in Wyoming through the process of refining sugar beets. In sugar beet processing, the lime is partly consumed and it is not sold as a product. Impure lime is stored as waste at sugar beet refining plants in Lovell, Worland, and Torrington.

Other lime used in Wyoming is purchased from commercial lime producers. The nearest commercial lime producers are Continental Lime Company at Townsend, Montana, the M.E.R.R. Co. near Tooele, Utah, and Calco, Inc., at Salida, Colorado.

There is a potential for commercial lime production in Wyoming because the State has many areas of easily-mined high-grade limestone resources, and it is located east of existing production in Montana and Utah. Apparently the major obstacles to the construction of a lime plant in Wyoming are transportation costs of the finished product.

Fertilizer

Fertilizer made from mined phosphate rock is produced in Wyoming at the Chevron Chemical Company plant near Rock Springs. Phosphate rock for this plant is mined near Vernal, Utah, and transported to the plant by slurry pipeline over the Uinta Mountains. In the plant, the phosphate is combined with sulfur derived from the processing of sour natural gas in western Wyoming. The resulting phosphate-based, acidic fertilizer is very suitable for agricultural regions located in relatively arid climates.

Fertilizer is also made in the Coastal Company's plant west of Cheyenne. Coastal Company, a division of Coastal States, was called WYCON until late in

1989. Coastal's fertilizer is urea-based and ammonia-rich and does not use large amounts of mined resources in its manufacture.

Silica raw materials

Studies of two high-silica sand or rock deposits were recently completed by the Geological Survey of Wyoming (Harris, 1988a and 1988b), and a third deposit is now under investigation in the Lovell area. This latter study as well as the previous studies have been partially funded through the Wyoming Economic Development and Stabilization Board. The primary reason for these investigations is the current interest in possibly producing glass in Wyoming.

This current interest is due to several factors: transportation rates in general have become more favorable; there are new ways of manufacturing and transporting glass; and there has been promising research into heat resistant ceramics, which may be substituted for metal in products such as automobile engines. In addition, there is also the possibility that some of Wyoming's silica deposits might be suitable for industrial use as aggregate in concrete or as hydrofrac sand.

All of the major raw materials used to make glass, including silica, soda ash (refined trona), feldspar, limestone, and pigments, are found within Wyoming's borders. Several companies are currently investigating the development of a glass plant in Wyoming. It appears now that a glass and ceramic manufacturing industry may be a real possibility in Wyoming's future.

Sulfur

According to the U. S. Bureau of Mines, Wyoming is now second in the Nation in terms of the production of sulfur from the processing of sour natural gas. Because sulfur demand is increasing at a rate of about six percent per year, there are markets for additional production of sulfur from Wyoming. Anticipated new demands for Wyoming's natural gas should provide this additional production.

Trona

With all the soda ash refineries in the State operating near their capacities, the production of soda ash (refined trona) and other sodium chemical products in Wyoming continued at record levels through 1989 (see *Wyoming Geo-notes* No. 23, p. 23). 1989 production should easily surpass the record set in 1988, and 1990 production should exceed all previous production levels. Since over ninety percent of the soda ash produced in the U.S. comes from Wyoming, market increases have had a direct affect on the State's trona industry.

The dramatic increase in soda ash production is related to increased demand by the traditional users of the sodium compound in glass, paper products, chemicals, and other items, the use of soda ash in the production of caustic soda, and the increased use of soda ash in the production of sodium cyanide.

The increased demand for sodium cyanide is a result of a dramatic increase in the production of gold in the United States. Sodium cyanide is commonly used to leach gold from its ore. Nationally, annual gold production has increased from about 960,000 ounces to 6,500,000 ounces in the past ten years. While sodium cyanide is currently only produced by the DuPont companies, FMC has started construction of a sodium cyanide plant in Wyoming. FMC's plant will begin production in the fall of 1990. This plant is expected to produce about 60 million pounds of sodium cyanide per year.

The sodium cyanide plant is only one of three plants under construction by FMC in the trona mining area near Green River. FMC is also constructing a sodium bicarbonate plant. This plant will have to compete with the existing Church & Dwight facility, but projected demand is expected to support two plants. The third plant under construction is a caustic soda plant.

To increase their soda ash production to accommodate these three new plants, FMC is streamlining its mining and refining operation. In this regard, FMC has added a new longwall mining machine to its underground operation.

URANIUM UPDATE

by Ray E. Harris, Industrial Minerals and Uranium Division Head, Geological Survey of Wyoming

Uranium mining and future plans

Uranium is now produced at only two localities in Wyoming. Everest Minerals and Malapai Resources mine uranium by *in situ*, solution-mining methods and produce yellowcake at the Highland property and the Irigary-Christensen Ranch property, respectively. Both of these operations are in the Powder River Basin.

In addition, a large Canadian mining company, Rio Algom, has acquired property formerly held by Kerr-McGee in the Powder River Basin. Rio Algom plans to construct an *in situ*, solution mine and a mill near the former site of Kerr-McGee's Bill Smith project. If these plans prove out, and if Malapai and Everest Minerals continue to increase their production as planned, *in situ* uranium production in Wyoming should show an increase again in 1990. Although these increases are very small compared to the boom years between 1973 and 1980, they are encouraging.

Wyoming's last producer of uranium by conventional open-pit mining methods closed its mill January 1, 1990. Pathfinder Mines is continuing to strip overburden from an ore body in the Shirley Basin in Carbon County. The Shirley Basin Mill is to remain closed at least for the winter. Pathfinder is owned by the French company COGEMA, and its production is tied primarily to COGEMA's contracts with foreign

utilities, especially some in the Far East. According to company officials, the mill will reopen when ore is mined again. The current low prices for yellowcake continue to take their toll of domestic operations.

The current price for yellowcake ($9.60 per pound) is even lower than the figure would indicate. For example, uranium prices were $6.00 to $8.00 back in the early 1950s when prices were set by the Federal government. Adjusting for inflation, today's price for yellowcake is less than $1.00 per pound relative to the prices in the 1950's. The current price may also be compared to an unadjusted price of $42.00 per pound in 1979.

Today, although some domestic uranium might be producible for less than $18.00 per pound, $18.00 is the average cost to produce the uranium in the United States that is minable by conventional methods. *In situ*, solution-mining methods, on the other hand, are apparently inexpensive enough that they can offer a viable alternative to conventional mining methods. This is why, even with the closure of most domestic uranium mines, certain *in situ* producers are expanding and constructing new facilities, like Rio Algom's planned operation in the Powder River Basin.

The U. S. nuclear power industry and fuel requirements

As of December 31, 1988, there were 108 operating nuclear power plants in the United States. These units generated a record 527 TeraWatthours (TWh), or 19.5 percent of all the electricity generated in the U. S. (Energy Information Administration, 1989a). This represents a continuing increase both in the number of nuclear units and in their percent of the total power generated in the U. S. The projected U. S. demand for yellowcake to supply existing and projected nuclear power requirements is shown in Table 10.

In this forecast, the demand for yellowcake increases in all but the "no growth scenario". After the present stockpile of yellowcake is depleted, requirements for yellowcake will have to come from newly-mined uranium. Whether these supplies

Table 10. PROJECTIONS OF U. S. YELLOWCAKE (U_3O_8) REQUIREMENTS, 1989-1995, 2001-2005, AND 2016-2020[1]

	Annual U_3O_8 requirement (million pounds equivalent U_3O_8)		
Time period	1989-1995	2001-2005	2016-2020
No growth scenario	37.4	35.2	20.0
Current projected demand	37.6	35.6	49.0
Highest projected growth	38.2	40.2	73.9

[1] Modified from Energy Information Agency, (1989b)

come from the U. S. (including Wyoming) or from foreign sources is a matter of both politics and economics. It is a fact that uranium can be mined in Canada and Australia more cheaply than in the U. S. One of the major reasons for this is that uranium deposits discovered in those countries are much higher grade than those that have been discovered in the U. S. Consequently, so much more uranium is produced per unit of ore that the price of Canadian and Australian yellowcake is much less than the price for lower grade deposits. While this dichotomy in the quality of ore deposits is a fact today, it should be remembered that much of the United States, including portions of Wyoming, have not been adequately explored for uranium deposits similar to those found in Canada and Australia. Given a viable domestic uranium industry, that exploration could resume and conceivably, new deposits, comparable in grade to the foreign ones, might be found.

In an effort to revive the domestic uranium industry, governors of several western states, including Wyoming's Governor Mike Sullivan, approved a resolution supporting Federal legislation that would help the western uranium mining industry. The resolution, offered by Governor Sullivan, supports a bill that would restructure the domestic uranium enrichment program, encourage the cleanup of abandoned mill tailings, and discourage the use of foreign uranium by the Nation's nuclear power industry. The resolution also noted that the United States imports more than half the uranium used by domestic nuclear plants, even though uranium is vital to national security.

Uranium reclamation projects

The cleanup of abandoned uranium mines and mill sites continues in certain areas in Wyoming. In 1990, reclamation is scheduled for an abandoned, 1950-vintage mine and small mill in northern Converse County. The mill site includes an unprotected waste pond that contains high concentrations of radioactive uranium daughter elements, toxic elements, and acidic compounds. The major concern with the remotely located mine and mill, called the Spook site, is its accessibility to livestock as well as wildlife. The contaminated material will be buried at the site in 49 to 65 feet deep pits lined with impermeable material. This project is expected to cost $4.12 million, which will come from the Federal Abandoned Mined Lands Reclamation Fund.

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METALS AND PRECIOUS STONES UPDATE

by W. Dan Hausel, Deputy Director, Geological Survey of Wyoming

In an effort that ended up involving the cooperation of five government agencies, the Geological Survey of Wyoming received nearly 12 tons of drill core from the U.S. Bureau of Mines. The Minnesota Air National Guard transferred the core from the U.S. Bureau of Mines' Minneapolis research facility to the Wyoming Air Guard at Warren Air Force base where the Wyoming Army National Guard picked it up and delivered it to the Geological Survey in Laramie. Thanks to all involved the odyssey came off without a hitch.

The core comes from the U. S. Bureau of Mines' 1940-vintage research projects on strategic minerals in Wyoming. Much of the core that we've been able to examine to date is from the Copper King mine in the Silver Crown district near Cheyenne, which is a copper-gold Proterozoic porphyry with large, low-grade reserves. According to the Bureau of Mines, there is also some core from the New Rambler copper-gold-platinum-palladium mine in the Medicine Bow Mountains, from a tungsten deposit in the Copper Mountain district, and from several other projects. Persons interested in viewing the core may do so by contacting W. Dan Hausel at (307) 766-2286.

Throughout 1989, company interest in Wyoming's metal and precious stone resources continued at a moderate pace. If inquiries to the Survey are any indication, the greatest interest is in gold, platinum, and palladium deposits. In addition to the inquiries on precious metals, however, the Survey received many inquiries about the State's copper, manganese, iron, diamond, and titanium resources. If prices for precious metals, copper, zinc, and titanium remain relatively high, Wyoming can expect to see more exploration dollars spent in 1990. And if these prices remain relatively stable and high over the next few years, there is a good chance that some gold or copper deposits might be developed in the State.

Additionally, the Metals and Precious Stones Division has begun preparation of a report on the State's titanium resources. Wyoming has numerous titanium deposits in nearly every basin of the State, as well as in the Laramie Mountains of Albany and Laramie Counties.

South Pass

In 1990, the Geological Survey of Wyoming will publish a report on the mineral resources of the South Pass greenstone belt. The report will emphasize gold occurrences, and its publication should stimulate additional company and prospector interest in the region, particularly if gold prices remain above $400 per ounce.

Briefly, investigations by the Geological Survey of Wyoming and others at South Pass indicate the presence of several small, but rich gold deposits as well as some large tonnage, low-grade gold deposits; a possible large tonnage, low-grade copper-

silver deposit; a very large resource of iron; a potential for nickel deposits; and possibly some very large, but buried, gold deposits.

Mineral Hill district, Black Hills uplift

During the Fall, the Metals and Precious Stones Division responded to a request to examine some properties in the Mineral Hill district of northeastern Wyoming. Mineral Hill is a Tertiary alkalic ring complex with a history of tin and gold mining. Samples of silicified trachyte, trachyte breccia, sulfide-bearing pyroxenite, and quartz veins were collected from various prospects in the district.

At the Artic mine located on the southwestern edge of Mineral Hill, selected samples of silicified trachyte were collected. These samples did not contain any anomalous gold or rare earth mineralization. Although no significant metals were detected, rock hounds will find some interesting rocks and minerals in this area. Samples of altered trachyte with drusy, purple, chalcedony fracture fillings were found, and amethyst crystals were discovered at the Artic #1 adit. This is one of only three documented localities for amethyst in Wyoming. The other two localities are the southern Absaroka Mountains near Yellowstone, and the Battle region of the Sierra Madre.

Other samples collected in the district were analyzed for a number of metals. Partial analyses of some of these samples are shown in Table 11, and the most interesting were those taken at the Treadwell open cut along the northwestern flank of Mineral Hill. Because samples of feldspathic breccia from the Treadwell yielded only background levels of gold, brecciation, at least at the Treadwell, was probably a post-mineralization event (samples TW1-89 and TW2-89).

Using a backhoe, TRYCCO Minerals exposed two buried mine tunnels in the highwall of the open cut. Both tunnels were driven on parallel, horizontal veins and the accompanying silicified trachyte host rock. Samples of the vein contained quartz, minor pyrite, and abundant limonite stains and limonite boxworks. Samples taken from the horizontal veins contain anomalous gold and silver (Table 11, samples TW4-89 through TW10-89).

Cooney Hills, Laramie Range

The Cooney Hills are a group of low-lying hills located along the eastern margin of the Elmers Rock greenstone belt. Historically, the hills were explored for copper and gold during the Great Depression and probably again in the latter part of the 20th century. No major mines were developed, but there are scattered mines and prospects on cupriferous veins and shear zones. At one locality in section 20, T.23N., R.69W. (the Whippoorwill mine), stratiform massive sulfides (pyrite) are exposed in a mica-quartz schist. This particular horizon is gossaniferous over a 4,000-foot strike length and a 20- to 40-foot width.

Samples collected in the Cooney Hills have only been partially analyzed. Unfortunately, the gold analyses are not yet available. Some other metals that were

Table. 11. GEOCHEMICAL ANALYSES OF SAMPLES FROM SOME RECENT GEOLOGICAL SURVEY OF WYOMING PROJECTS.

Sample #	Description	Au (ppm)	Ag (ppm)	Pt (ppm)	Pd (ppm)	Cu (%)	Fe (%)	Cr (ppm)	Ni (ppm)	MgO (%)
- MINERAL HILL DISTRICT -										
BSE 1-89	Pyroxenite with disseminated pyrite from Birdseye mine.	0.168	—	< 0.005	0.004	—	—	—	—	—
BSE 2-89	Mafic breccia with minor pyrite from Birdseye mine.	0.002	—	< 0.005	0.008	—	—	—	—	—
TWI-89	Grab sample of feldspathic breccia from Treadwell open cut.	< 0.005	< 5	—	—	—	—	—	—	—
TW2-89	Feldspathic breccia from highwall.	< 0.005	< 5	—	—	—	—	—	—	—
TW4-89	Quartz vein with limonite boxworks from western tunnel.	>10.0	>300	—	—	—	—	—	—	—
TW6-89	Silicified trachyte with quartz veinlets from western tunnel.	1.39	9.0	—	—	—	—	—	—	—
TW8-89	Quartz with boxworks from eastern tunnel.	0.360	< 5	—	—	—	—	—	—	—
TW9-89	Vertical fracture cutting vein.	0.056	< 5	—	—	—	—	—	—	—
TW10-89	Quartz vein with boxworks.	9.26	65.0	—	—	—	—	—	—	—
- KEYSTONE DISTRICT, MEDICINE BOW MOUNTAINS -										
IDPI-89	Limonitic quartz with minor malachite stains, Independence mine.	—	1.2	—	—	1.08	—	—	—	—
IDP2-89	Fractural milky quartz with massive limonite.	—	0.8	—	—	0.09	—	—	—	—
FLI-89	Six-inch wide chip sample of silicified quartz diorite from Florence mine.	0.21	2.3	—	—	0.03	—	—	—	—
FL2-89	Limonite-stained quartz diorite.	0.60	1.3	—	—	—	—	—	—	—
FL3-89	Quartz, minor limonite	0.54	—	—	—	—	—	—	—	—
FL5-89	Limonite after pyrrhotite and siderite in quartz diorite.	0.92	—	—	—	—	—	—	—	—
KS2-89	Milky quartz with minor pyrite and common limonite boxworks from Keystone Mine.	22.0	2.6	—	—	—	—	—	—	—

KS3-89	Massive milky quartz with disseminated pyrite and limonite after pyrite and siderite.	2.1	—	—	—	—	—	—	—	—
KS4-89	Quartz breccia vein with limonite stains.	< 0.05	< 1.0	—	—	—	—	—	—	—
	- McCANN PASS, HARTVILLE UPLIFT -									
MPI-89	Cupriferous gossan from Charter Oak mine.	< 0.05	< 1.0	—	—	8.6	—	—	—	—
MP2-89	Limonite gossan	< 0.05	< 1.0	—	—	1.4	—	—	—	—
	- RED DESERT BASIN -									
RDSI-89	Wilfley table concentrate of sand from dry drainage.	2.4	—	—	—	—	—	—	—	—
	- SEMINOE MOUNTAINS -									
BP2-88	Quartz with sulfide and limonite from Deserted Treasure mine dump.	28.0	18.0	—	—	0.39	—	—	—	—
BP3-88	Quartz with sulfide and limonite from Emmuleta mine dump.	20.0	18.0	—	—	0.38	—	—	—	—
BP4-88	Quartz with sulfides from King mine dump.	0.87	—	—	—	0.06	—	—	—	—
BP2-89	Cupriferous limonitic quartz from King dump.	1.2	3.6	—	—	—	—	—	—	—
BP3-89	Limonitic quartz in fold closure, south of Deserted Treasure mine.	6.8	4.2	—	—	—	—	—	—	—
BP4-89	Banded iron formation with hematitic boxworks.	0.051	< 5	—	—	—	29.0	—	—	—
BP13-89	Mafic schist	0.005	< 5	< 0.005	0.002	—	—	1,100	160	11.9
BP14-89	Spinifex textured metagabbro	0.047	< 5	0.007	0.005	—	—	440	110	8.87
BP15-89	Spinifex textured metagabbro	0.001	< 5	0.009	0.006	—	—	370	73	8.54
BP22-89	Serpentinite	< 0.005	< 5	—	—	—	—	6,680	1,600	32.5
BP23-89	Metaperidotite	< 0.005	< 5	—	—	—	—	2,400	970	28.5
BP24-89	Metaperidotite	< 0.005	< 5	—	—	—	—	7,330	1,700	30.6
BP27-89	Spinifex textured metagabbro	< 0.005	< 5	—	—	—	—	930	140	12.4

tested included gallium, tin, and tungsten. These were not anomalous and occurred in background-level concentrations.

Keystone district, Medicine Bow Mountains

When gold was discovered in the Keystone district in the 1860s, several rich veins were associated with the Keystone quartz diorite. Rich placers were also found in the adjacent Douglas Creek and its tributaries. The Keystone district includes several historical mines developed on N60°W-trending shears and veins subsidiary to the Nash Fork-Mullen Creek shear zone, which is a major suture zone dividing the Medicine Bow Mountains into two different tectonic terranes. The principal ore bodies were developed on veins in narrow shears, and on vein intersections. The shear structures are from 2 to 6 feet wide and splay to as much as 300 feet wide locally.

Partial analyses of some samples collected in the district are listed in Table 11. The most interesting samples were collected from the Keystone mine dump (KS2-89 and KS4-89), but this is not surprising considering the numerous samples from this mine that have yielded anomalous gold assays (see Hausel, 1989a, p.124). Two of the samples showed anomalous gold with values of 2.1 ppm (0.06 oz/ton) and 22.0 ppm (0.64 oz/ton) gold. A brief examination of the mineralized zone revealed some tight folding associated with the shear structure.

McCann Pass, Hartville uplift

The Hartville uplift in eastern Wyoming includes a relatively well preserved eugeosynclinal section of Archean metasedimentary and metavolcanic rock. For nearly a century, iron ore was mined in the region from a group of hematite schists from several mines and prospects including the Sunrise, Chicago, Central, Michigan, and Good Fortune mines.

The McCann Pass fault northeast of the Sunrise mine has some impressive massive sulfides (pyrite) and associated gossans, which were locally mined near the turn of the century. In places, the gossans are so prominent that the area has been called "gossan hill". Samples collected from the historic Charter Oak mine along this structure yielded anomalous copper mineralization (Table 11).

Red Desert Basin

The Red Desert Basin has produced some enigmatic gold anomalies. For example, Albert (1986) reported stream-sediment samples yielded values as high as 6.55 ppm gold. The author recently collected two stream-sediment samples in the basin south of Crooks Gap and had them tested for gold (sections 2 & 10, T.26N., R.93W.). These samples, which were collected from poorly developed dry drainages within one foot of the surface, were concentrated on a Wilfley table. One of the two samples assayed 2.4 ppm gold (Table 11, sample RDS1-89)!

These gold occurrences are intriguing in that they appear to be relatively widespread across the State (see Albert, 1986; Hausel, 1989a). The gold occurrences, whether they are of detrital or geochemical origin, may end up representing a whole new class of gold deposits previously overlooked by exploration geologists.

Seminoe district, Seminoe Mountains

Little is really known about the mineral deposits in the Seminoe Mountains of central Wyoming. Copper and jade occur in the district; the iron resources are enormous; and potential for commercial gold mineralization appears to be high based on the relatively common occurrence of visible gold in vein samples.

Field investigations of this region by the Geological Survey of Wyoming began in the late summer of 1989. The Survey is mapping the district on a 1:24,000 scale and is sampling veins, shear zones, and gossans at the base of komatiite successions for gold, nickel, and chromium. Samples taken to date indicate this greenstone belt is worthy of serious examination. Using previous mapping and recent reconnaissance mapping by the Survey, a preliminary map of the district was completed this Fall (Hausel, 1989b). The map shows a complex network of veins on Bradley Peak, and thick basaltic komatiite and serpentinite units in the district.

Samples collected from the veins, show that these quartz-carbonate-sulfide structures are highly mineralized. In 1981, the author collected several samples in this area that assayed as high as 98.4 ppm (2.87 oz/ton) gold. Some of these samples exhibited visible gold. More recently, vein samples collected in the district also showed anomalous gold (Table 11). The vein samples ranged from 0.87 ppm (0.025 oz/ton) to 28 ppm (0.82 oz/ton) gold.

Serpentinites and spinifex textured basaltic komatiites all have relatively high chromium and nickel contents. Of the few samples assayed to date, nickel contents were from 73 ppm (0.007 %) to 1,700 ppm (0.17 %), and chromium contents were from 370 ppm (0.04%) to 7,330 ppm (0.73 %) (Table 11).

Seminars and field trips

Last Fall, the Metals and Precious Stones Division offered an afternoon Prospecting Seminar to interested individuals. Because of the favorable response and interest, the division will try to make similar seminars on prospecting techniques, gold resources, gold geology, diamonds, mineral resources, regional geology, field trips, etc., available to any group or company upon request. Interested parties may contact W. Dan Hausel at the Geological Survey of Wyoming during most business hours.

References cited

Albert, K.A., 1986, Reported gold concentrations in sediment samples from U.S. Department of Energy's National Uranium Resource Evaluation (NURE)

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Hausel, W.D., 1989a, The geology of Wyoming's precious metal lode and placer deposits: Geological Survey of Wyoming Bulletin 68, 248 p.

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NEW ESTIMATES OF COMPLIANT COAL RESERVES? DON'T BET ON IT!

by Gary B. Glass, State Geologist, and Richard W. Jones, Coal Division Head, Geological Survey of Wyoming

In the last quarter of 1989, the U. S. Energy Information Administration (EIA) published a "new" report titled, *Estimation of U. S. coal reserves by coal type—heat and sulfur content* (EIA, 1989). This outwardly impressive report tabulates coal reserves by state and purports to categorize the reserves by their sulfur content in pounds/million Btu. Using this report, one can presumably find out how much of the coal reserves in the U. S. are low enough in sulfur that they can be burned in power plants without scrubbers, i.e., compliant coal. While the report does show that Wyoming has very large recoverable reserves of compliant, low-sulfur coal (<0.40 - 0.60 lbs. of sulfur/million Btu), its estimate of Wyoming's strippable reserves for these categories of sulfur content is probably only about half of what it should be.

Without looking at any coal other than the Wyodak coal bed in the Powder River Basin of Wyoming, we estimate that the recoverable strippable reserves in the sulfur category of <0.40 - 0.60 lbs. of sulfur/million Btu should have been at least 17.3 billion tons. The EIA's report only lists 7.8 billion tons in this category. What's more, EIA only shows 247.8 million tons of that estimate in the lowest sulfur category (<0.40 lbs. of sulfur/million Btu). A quick estimate of the coal quality in Wyoming's existing mines indicates there is probably at least 3.7 billion tons of strippable coal reserves in the category of <0.40 lbs. of sulfur/million Btu. Carrying our spot check of EIA's estimates one step further, we estimate that there is close to 11.3 billion tons of <0.40-category coal just in reserves of the Wyodak coal bed in the Powder River Basin. There are, of course, many other low-sulfur coals in Wyoming besides the Wyodak coal bed.

Also, despite an occasional footnote that may allude to problems in calculating sulfur dioxide emissions from these data, the EIA really avoids mentioning previous

investigations that have shown that many lower rank coals retain some sulfur in their ash when they are burned. In fact, an earlier report, which is cited in the EIA report, says just that (Hamilton, and others, 1975). Quoting from Hamilton, and others (1975), "Combustion tests on a steam-electric powerplant burning Wyoming subbituminous coal indicate about 72-percent conversion of sulfur to a stack emission of sulfur dioxide."

At least in the case of Wyoming, it is our conclusion that the EIA's underestimation of compliant, low-sulfur strippable coal reserves stems from their use of an old, grossly inaccurate, 1971-vintage data base for their coal quality information. The inadequacy of that data base has been described by Glass (1981, p. 540). The data on Wyoming, is simply not accurate and understates the quantity of compliant coal reserves in the State by perhaps as much as 9.5 billion tons. While we really cannot comment on the credibility of the EIA's estimates for other states, all users should be aware of these kinds of potential problems when they examine EIA's (1989) report.

EIA is also aware of many of these problems and they are convening a Coal Reserves Assessment Conference at Arlington, Virginia on February 7th and 8th, 1990. The conference goal is to plan a new cooperative program to compile timely new reserve estimates to improve the EIA's data base. Presumably the conference will also address how to add coal quality information to new reserve estimates.

While starting a new data base now may be a little late for some concerns over the distribution and quantities of existing compliance coal, it could be very timely for the not too distant future when coal will be used for something other than a fuel. Data on coal quality may well be invaluable for these anticipated uses of coal, particularly if the quality information includes more than just sulfur content. We already know that other major and minor elements in coal can affect its behavior even in different combustion processes. The same is true when coal is converted to liquid or gaseous products. As a chemical feedstock, who knows what quality information will be important. We do know that the area of coal characterization (determination of the chemical and physical properties of coal) is the singlemost important goal of the State Survey's Coal Division for the foreseeable future.

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Energy Information Administration, 1989, Estimation of U. S. coal reserves by coal type—heat and sulfur content: U. S. Department of Energy Report DOE/EIA-0529, 57 p.

Glass, G. B., 1981, A critical evaluation of published western coal-resource estimates: Geological Society of America Bulletin, Part I, v. 92, p. 538-541.

Hamilton, P. A., and others, 1975, The reserve base of U. S. coals by sulfur content, Part 2. The western states: U. S. Bureau of Mines Information Circular 8693, 322 p.

GEOLOGIC MAPPING AND STRATIGRAPHY

by Alan J. Ver Ploeg, Stratigraphy Division Head, Geological Survey of Wyoming

An important new stratigraphic project relating to the Cretaceous-age sedimentary depositional history of the Western Interior basin was recently initiated. The project, referred to as the Western Interior Cretaceous Project (WIK), will include a publicly-available computerized data base from which the depositional history of Laramide basins and adjacent areas can be reconstructed and interpreted. This data base will also allow comparison of Western Interior basins with basins around the world.

The initial phase of the project will be the compilation of surface and subsurface reference sections for each of the basins in the study area. These sections will be annotated using as much sedimentologic, paleontologic, geochemical, petrophysical, geophysical, and resource data as available. This information along with constructed stratigraphic cross sections will be presented as a poster session at the 1990 Rocky Mountain Section meeting of the American Association of Petroleum Geologists in Denver, Colorado.

The second phase of the project will include construction of regional stratigraphic cross sections, time-stratigraphic cross sections, paleogeographic maps, and basin-wide interpretations. A stratigraphic atlas for the general study area is expected to be the final published product of the project.

The overall project leader is Robert Weimer. The coordinator for the Wyoming, Utah, and Nebraska region is Frank Ethridge from Colorado State University. In Wyoming, the project will include the Powder River Basin-SE, Powder River Basin-NW, Wind River Basin, Laramie Basin, Red Desert Basin, Green River Basin, Moxa Arch, and Jackson Hole. The Denver Basin is included in the Colorado, Utah, and Kansas region, which will be coordinated by T.D. Fouch. The Stratigraphy Division of the Geological Survey of Wyoming will assist the University of Wyoming's Department of Geology and Geophysics in compiling the data base and interpretation for the Laramie Basin.

Work is nearly completed on a new, 1:100,000 scale, full-color, geologic map of the Nowater Creek, Wyoming, Quadrangle. The Division is compiling the map from existing geologic maps of the U.S. Geological Survey, the Geological Survey of Wyoming, and both in-state and out-of-state thesis mapping. In addition, the Division is producing photogeologic maps covering areas in this quadrangle that have only been mapped on a regional basis. Two areas in particular have required this more definitive new mapping. They are (1) an area east of Tensleep, Wyoming on the west flank of the Bighorn Mountains, south of the Tensleep fault and (2) an area west of the Nowood River in the central portion of the map. To date, three 1:24,000 scale quadrangles have been mapped using true color and color-IR photography. An area covering approximately two to three 1:24,000 scale quadrangles remains to be

mapped with photography. The entire map should be completed and published this calendar year.

As a final note, Robert Bakker, a vertebrate paleontologist from the University of Colorado, reported a potentially significant discovery of an apparent new species of the rare Othnielia dinosaur family. Late last summer, two amateur paleontologists made the discovery in the Como Bluffs area, a noted dinosaur locality for over a century. The two amateur paleontologists, Jim Filla of Nederland, Colorado and Jim Siegwarth of Boulder, Colorado brought the fossil bone fragments to Bakker who immediately recognized them as belonging to the Othnielia family. The fact that the specimen was a baby made the discovery even more important since very few baby dinosaurs have been found. An adult of this species was about five feet long, over half of which was tail, and weighed less than 100 pounds. It somewhat resembled a kangaroo and lived during earliest Jurassic time, approximately 135 million years ago.

EARTHQUAKES AND ACTIVE FAULTS

by James C. Case, Geologic Hazards Division Head, Geological Survey of Wyoming

Earthquake education

Awareness of earthquake hazards can result in a significant savings of life and property in the event a strong to major earthquake occurs. Because major earthquakes have occurred in or near Wyoming, they will certainly occur again in the future. For this reason, improving and expanding earthquake education at the primary and secondary school level is a priority for the Geological Survey of Wyoming and the Wyoming Emergency Management Agency.

As a result of attending the Federal Emergency Management Agency's (FEMA's) First Biennial Earthquake Program Information Exchange Workshop in March, 1989, the State Survey acquired quantities of earthquake brochures, Big Bird buttons that read "Get ready for earthquakes", and other educational tools. In fact, there were enough copies of *Earthquakes: a teacher's package for K-6* and a booklet titled *Guidebook for developing a school earthquake safety program* to send one to every school in the State.

The Geological Survey of Wyoming's exhibit at the 1989 Wyoming State Fair also featured information about earthquake hazards. Over 500 Big Bird buttons were distributed to persons visiting the exhibit. Distribution of the buttons was such a success that it will probably be an annual feature.

The Wyoming Emergency Management Agency is also planning another Wyoming Hazards Awareness Week. They have tentatively slated it for April 1-7, 1990.

Research on active faults

Research on active faults in Wyoming is primarily concentrated along the western edge of the State. Dr. Ken Pierce and Dr. Lisa Morgan (U.S. Geological Survey, Denver) have written a manuscript on patterns of neotectonic faulting associated with the track of the Yellowstone hot spot. Dr. Pierce is continuing his studies of Quaternary faulting and other deformation in northern Yellowstone National Park and in Jackson Hole. Pierce is also studying geomorphic indicators of uplift and subsidence in northwestern Wyoming, particularly in the Bighorn Basin.

Dr. Bob Smith and his students at the Department of Geology and Geophysics at the University of Utah continued and expanded their research on the earthquake hazards of the Grand Teton National Park, particularly in regard to the Teton fault. To date, the following research has been completed:

1) Detailed mapping of the Teton fault at a scale of 1:9,000 to include an assessment of segmentation, relative ages and multiplicity of slip events, and likely locations for earthquake nucleation.

2) Relationships of the fault to bedrock and glacial geology.

3) EDM profiling of the scarp at 21 locations to assess scarp diffusion and age.

4) Establishment of a 22-kilometer-long, 1st-order level line across the middle segment of the fault for measuring tectonic deformation.

5) Trenching of the Teton fault.

In addition, Dr. Jim McCalpin of Utah State University has received funding from the National Earthquake Hazards Reduction Program to study the latest Quaternary faulting in the northern Wasatch to Teton corridor. In 1990, he will trench the Star Valley fault in western Wyoming. It is estimated that movement along this fault could generate up to a magnitude 7.5 earthquake.

Rocky Mountain Section meeting of the Geological Society of America

The 1990 meeting of the Rocky Mountain Section of the Geological Society of America (GSA) will be held in Jackson, Wyoming on May 21-23, 1990. Field trips will be held two days before and three days after the formal meeting. At least three of the field trips relate to earthquakes or active faults. On May 19-20, Dr. Mark Auders (Lamont-Doherty Geological Observatory), Dr. David Rodgers (Idaho State University), Dr. James McCalpin (Utah State University), and Kathy Haller (U.S. Geological

Survey) will lead a field trip on the "Late Tertiary and Quaternary faulting north and south of the Eastern Snake River Plain." On May 20, Dr. Ken Pierce (U.S. Geological Survey) will lead a field trip on the "Quaternary geology of Jackson Hole, Wyoming". On May 24, Dr. Bob Smith (University of Utah), John Byrd (University of Utah), and David Sussong (U.S. Geological Survey) will lead a trip on the "Teton fault zone and Quaternary evolution of the Teton Range". Jim Case of the Geological Survey of Wyoming is the coordinator for the GSA field trips. Please contact him for additional information at (307) 766-2286.

NEW PUBLICATIONS BY THE GEOLOGICAL SURVEY OF WYOMING

*Basement map of Wyoming: contours and structural configuration by D.L. Blackstone, Jr.: Map Series 27, 1990 revision ($4.00).

*Bibliography and index of graduate theses and dissertations of the Department of Geology and Geophysics, University of Wyoming by C.L. Van Burgh, G.B. Glass, and S.M. Roberts: Information Pamphlet 3, 1989 (free).

*Selected bibliography on selenium, by James C. Case, Linda R. Zellmer, Mary T. Harris, Rebecca L. Anderson, and Laura Larsen: Open File Report 89-7, 1989 ($10.00).

*Mica in Wyoming by Ray E. Harris: Open File Report 89-8, 1989 ($2.00).

*Temporal distribution of the ultramafic-allkalic and alkalic rocks within the Russian, Siberian, and North American ancient platforms and their surroundings by E.I. Erlich, W.M. Sutherland, W.D. Hausel, and I.A. Zagruzina: Open File Report 89-9, 1989 ($4.00).

*Precambrian geology of the Seminoe gold district, Bradley Peak Quadrangle, Carbon County, Wyoming, compiled by W.D. Hausel: Open File Report 89-10, 1989 ($3.50).

*Graphite in Wyoming by Ray E. Harris: Open File Report 89-11, 1989 ($2.00).

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

Order these and other publications from: Geological Survey of Wyoming, Box 3008, University Station, Laramie, Wyoming 82071-3008. Phone: (307) 766-2286. Many of these publications are also available over-the-counter at the Wyoming Oil and Gas Conservation Commission (Basko Building) in Casper, Wyoming.

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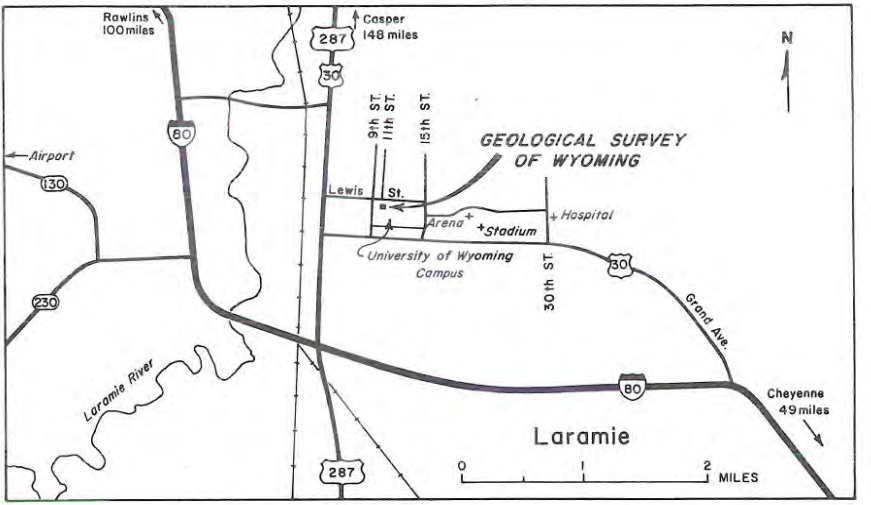
— NEW SERVICE AVAILABLE —

By special arrangement with the Wyoming Geological Association (WGA), the Geological Survey of Wyoming now sells all of WGA's Annual Field Trip Guidebooks as well as its Symposium Volumes. These publications are available over-the-counter at the Survey's offices on the University campus in Laramie. Although they can be purchased by mail, prepayment is required. Call the Survey for book prices and postage costs. WGA sale prices will be honored also.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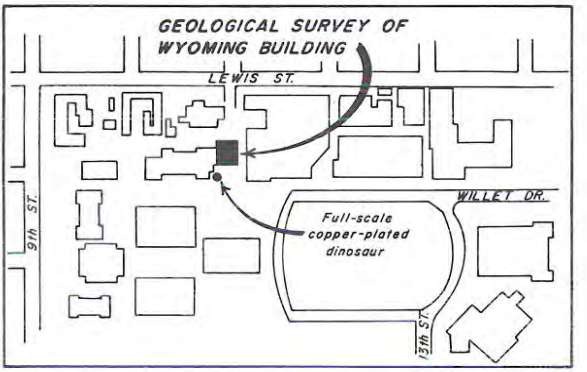
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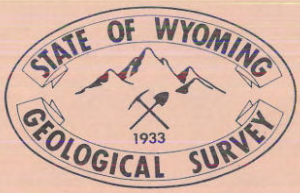
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