CHEMICAL ANALYSIS AND EVALUATION OF 40 SAMPLES FROM UPPER CRETACEOUS COAL BEDS FROM THE WIND RIVER BASIN, WYOMING

by

Ralph C. Warlow, Linda J. Bragg, John F. Windolph, Jr.,
Nelson L. Hickling, Joanne K. Oman, Patricia T. Kerr,
and James W. Baker

A discussion of rank, major- and minor-element content and depositional environments of 40 coal samples from the Wind River Basin, Wyoming

Open-file Report 86-187

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or stratigraphic nomenclature.

1987

Contents

Illustrations

Tables

Chemical Analysis and Evaluation of 40 samples from Upper Cretaceous Coal Beds from the Wind River Basin, Wyoming

by

Ralph C. Warlow, Linda J. Bragg, John F. Windolph, Jr. Nelson L. Hickling, Joanne K. Oman, Patricia T. Kerr, and James W. Baker

Abstract

Detailed chemical analysis of 40 drill-core samples (reported on whole-coal and laboratory-ash basis) from the Wind River Basin, Wyoming, indicate that 29 of the coals are subbituminous A, B, and C in rank. Eleven samples are bituminous C in rank, probably the results of intense deformation in the northwestern corner of the basin and depth of burial in the central part of the basin. The quality of the Wind River Basin coal is similar to other sampled western subbituminous coals. Chemical elements which are of environmental concern are found in the Wind River Basin coal beds in approximately the same concentrations as they are found in other sampled western subbituminous coals.

The major coal-bearing sequences in the western Wind River Basin are in the Mesaverde and Meeteetse Formations and a minor occurrence is in the Frontier Formation, all of Cretaceous age. Organic matter accumulated in an extensive coastal swamp environment on a prograding delta system during deposition of the Frontier and Mesaverde Formations. In contrast, peat in the Meeteetse Formation developed in a more restricted intermontane basin which was subjected to tectonic deformation accompanied by considerable amount of air laden with volcanic ash. These contrasting depositional environments have resulted in differences in the coal chemistry and quality. Coals in the Mesaverde Formation generally contain more iron and sulfur,whereas those in the Meeteetse Formation contain more ash, calcium, and silica.

Coals in the Wind River Basin have a higher ash-fusion temperature than other sampled western coals and should be highly competitive in the marketplace for combustion processes.

Introduction

The Wind River Basin (fig. 1) includes approximately 8,500 square miles in west central Wyoming, largely in Fremont, Natrona, and Hot Springs Counties.

The basin is bounded on the north by the southern Bighorn Mountains, the Owl Creek Mountains, and the Washakie range; on the southwest by the Wind River Mountains; on the south by the Granite Mountains (Sweetwater Arch); and on the east by the Casper Arch. Except for the Casper Arch (fig. 1), the surrounding uplifts have exposed cores of Precambrian crystalline rock. The deepest part of the basin contains sedimentary rocks whose aggregated thickness may be more than 26,000 ft.

The Mesaverde and Meeteetse Formations of Late Cretaceous age are the major coal-bearing strata in the western Wind River Basin, and underlie approximately 5,500 square miles. Several coal beds in the Mesaverde and Meeteetse Formations are as much as 240 in. thick. These formations are limited to isolated outcrops of low dip angle in the south and southwest parts of the basin and steeply dipping to overturned, folded, and faulted strata in the north and northwest part of the basin (fig. 2). A minor deposit of coal in the Frontier Formation, near the town of Wilderness, locally is as much as 42 in. thick. A near-surface channel sample (W210031) is the only source of data on this coal bed.

Previous investigations

The Wind River Basin was included in the early geologic investigations of F.V. Hayden in 1869.

The geology in the northern part of Fremont County, Wyoming, was investigated by T.B. Comstock (1874) and by G.H. Eldridge (1894). W.C. Knight (1895) summarized the coal fields in Wyoming and E.G. Woodruff (1907) prepared a detailed report on the Lander coal field. In 1906, N.H. Darton made a stratigraphic study of the Paleozoic and Mesozoic rocks of central Wyoming. In 1912, Woodruff and Winchester completed an investigation of the coal resources of Cretaceous and Tertiary strata in the Wind River Basin. H.L. Berryhill and others (1950) estimated the coal resources of Wyoming. Thompson and White (1952) described the geology and coal resources of the Alkali Butte, Big Sand Draw, and Beaver Creek coal fields.

W.R. Keefer and others (1957, 1961, 1964, 1970, 1972) prepared numerous detailed geologic reports on the stratigraphy and structure of the Wind River Basin, as well as geologic maps and oil and gas investigations. D.A. Seeland and E.F. Branch (1975) compiled a mineral-resource investigation for the Bureau of Indian Affairs in 1975, and a coal-resource report on the Wind River Basin was updated by Glass and Roberts in 1978.

Present investigations

This report evaluates the chemical analyses of coal samples collected during a geologic study of the western Wind River Basin. These data describe the quality of the coal collected from 39 drill-core samples and one outcrop sample (figs. 3, 4, 5, and 6). Stratigraphic distribution and sample numbers are shown in figure 6. Chemical data indicate that the rank of the coal ranges from subbituminous C to high-volatile bituminous C (table 1).

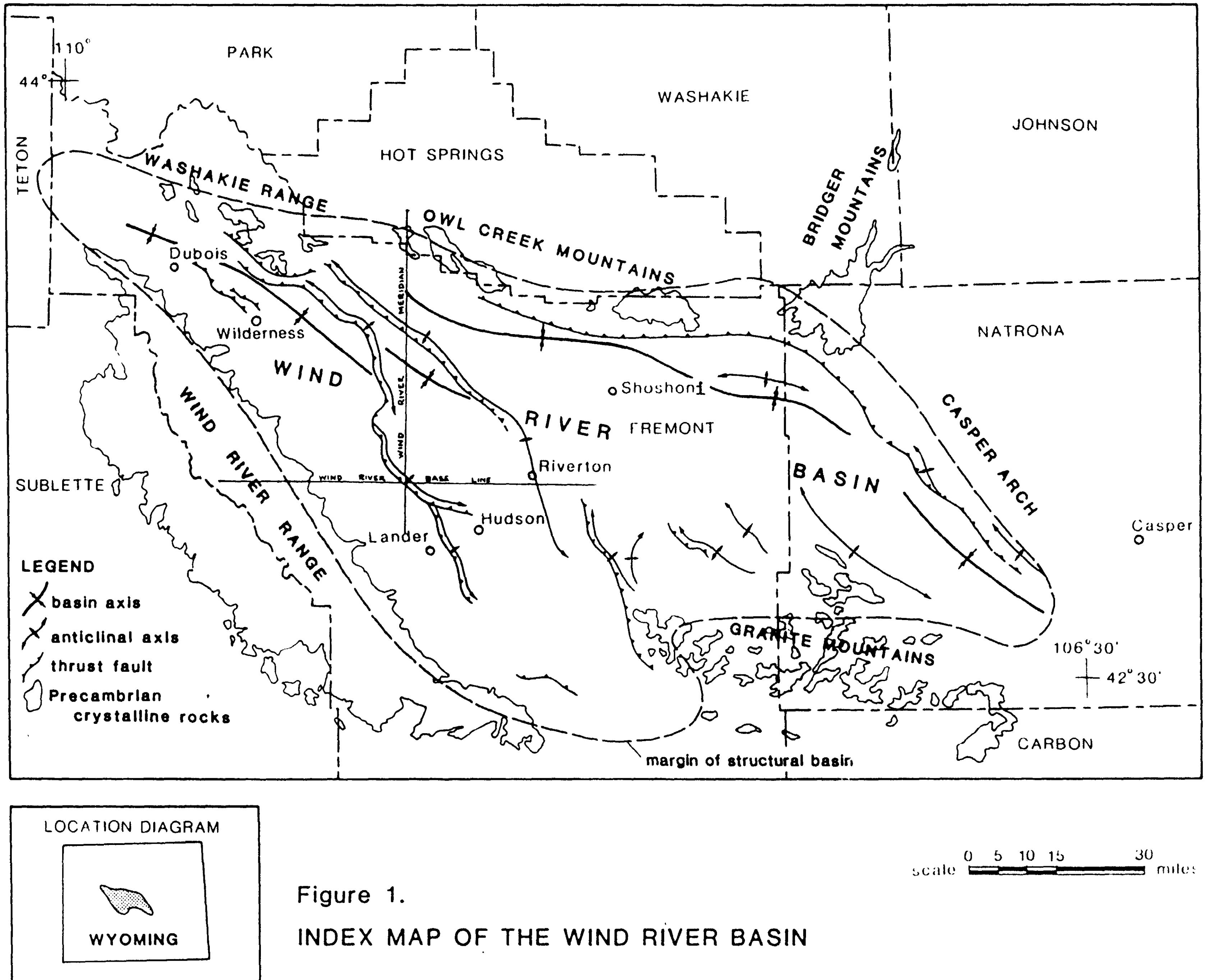

Figure 1.

INDEX MAP OF THE WIND RIVER BASIN

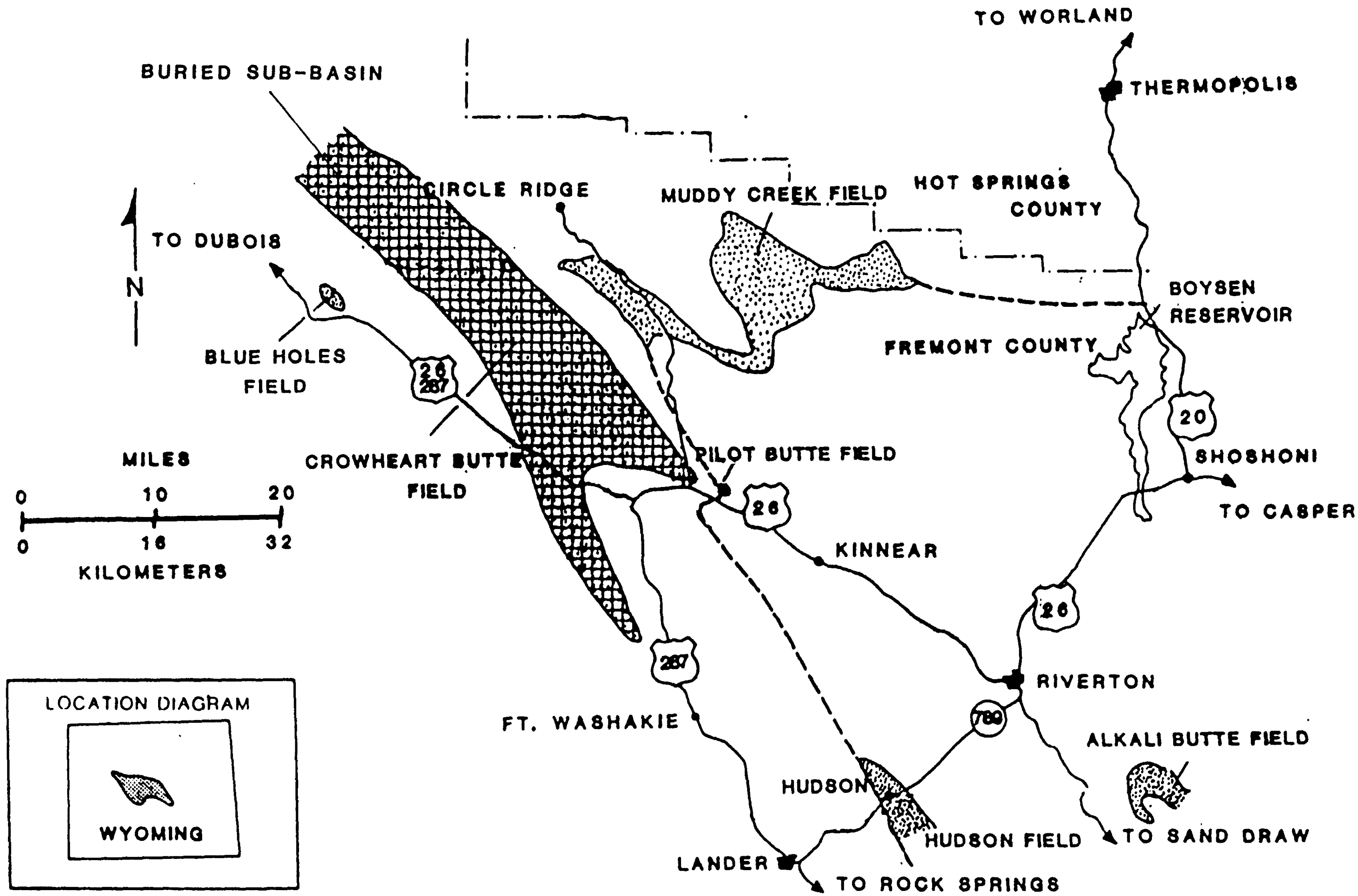

Figure 2 Coal COAL FIELDS IN THE WESTERN WIND RIVER BASIN

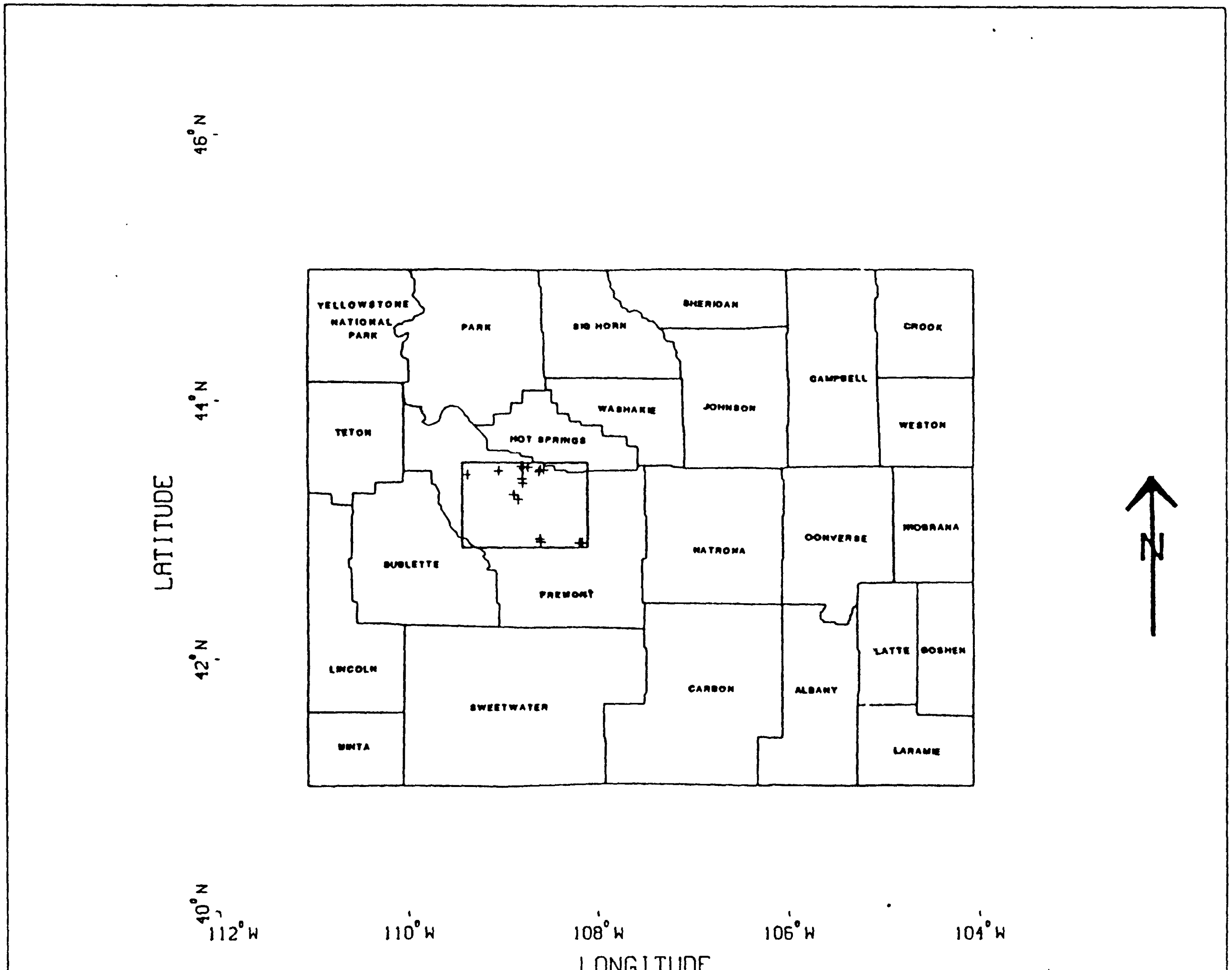

Figure 3. - Location of Coal Sample Sites in Fremont County, Wyoming.

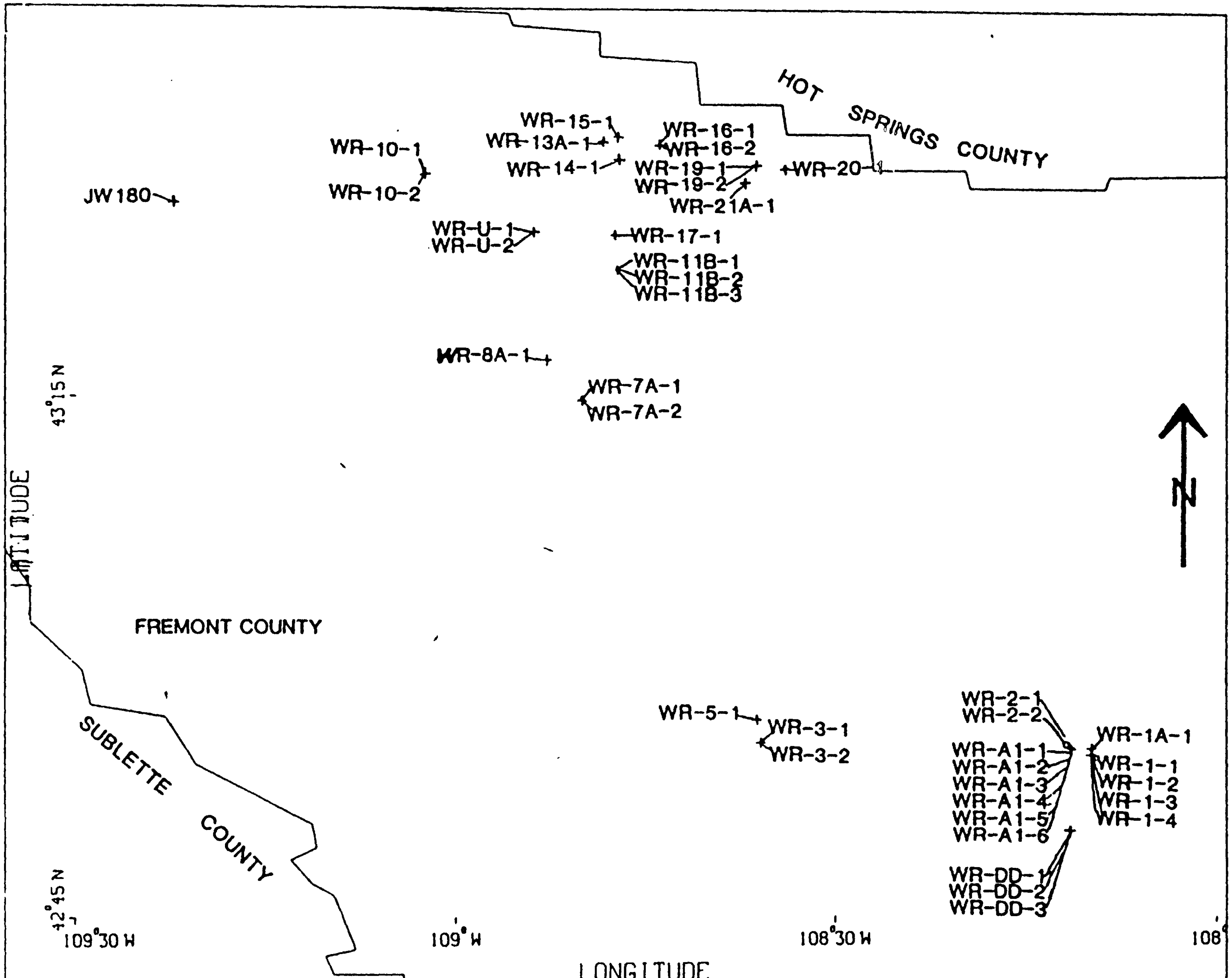

Figure 4. - Computer plot showing location of drill-core holes and outcrop sample distribution, and field identification numbers

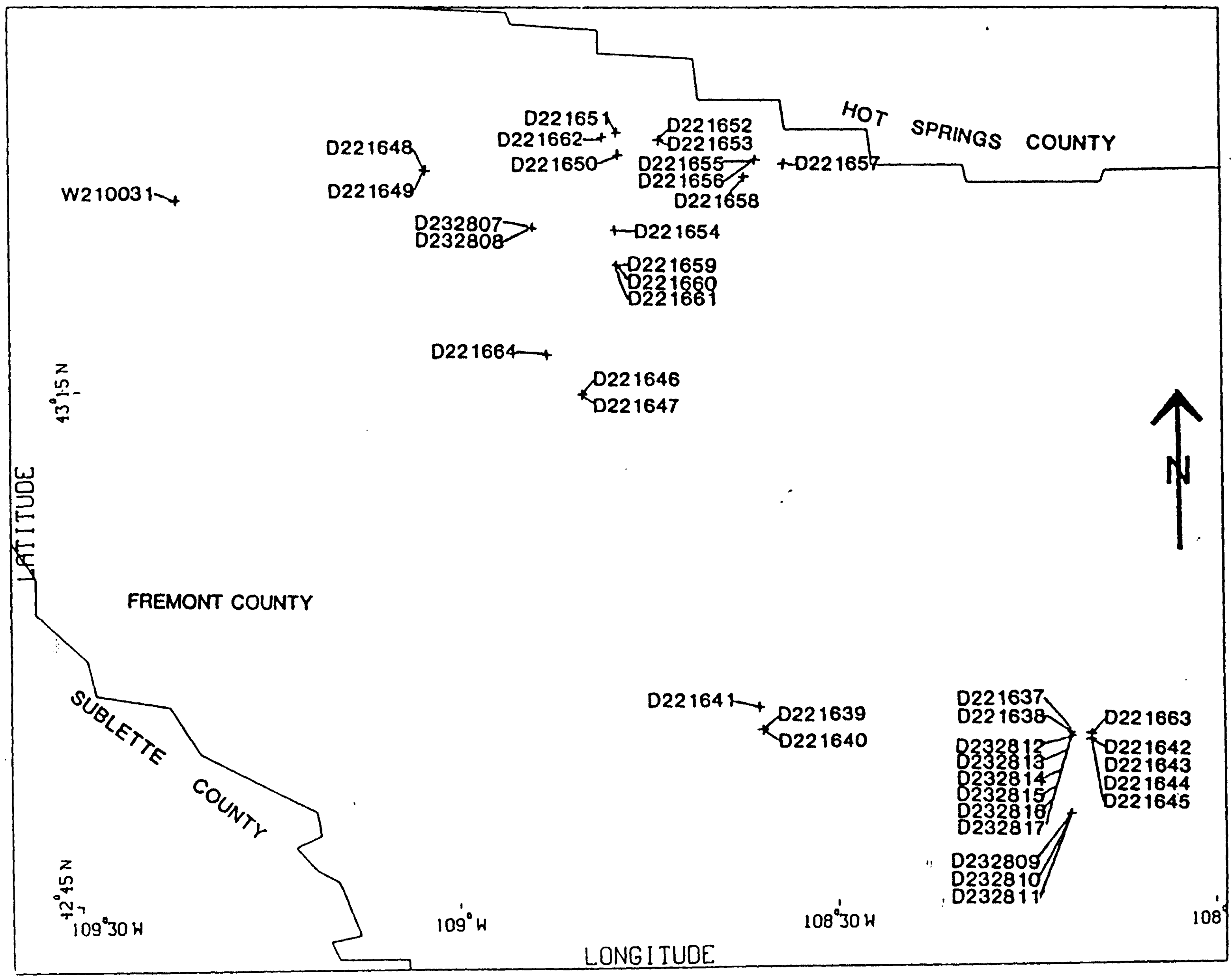

Figure 5. - Computer plot showing location of drill-core holes outcrop, sample distribution, and laboratory identification numbers

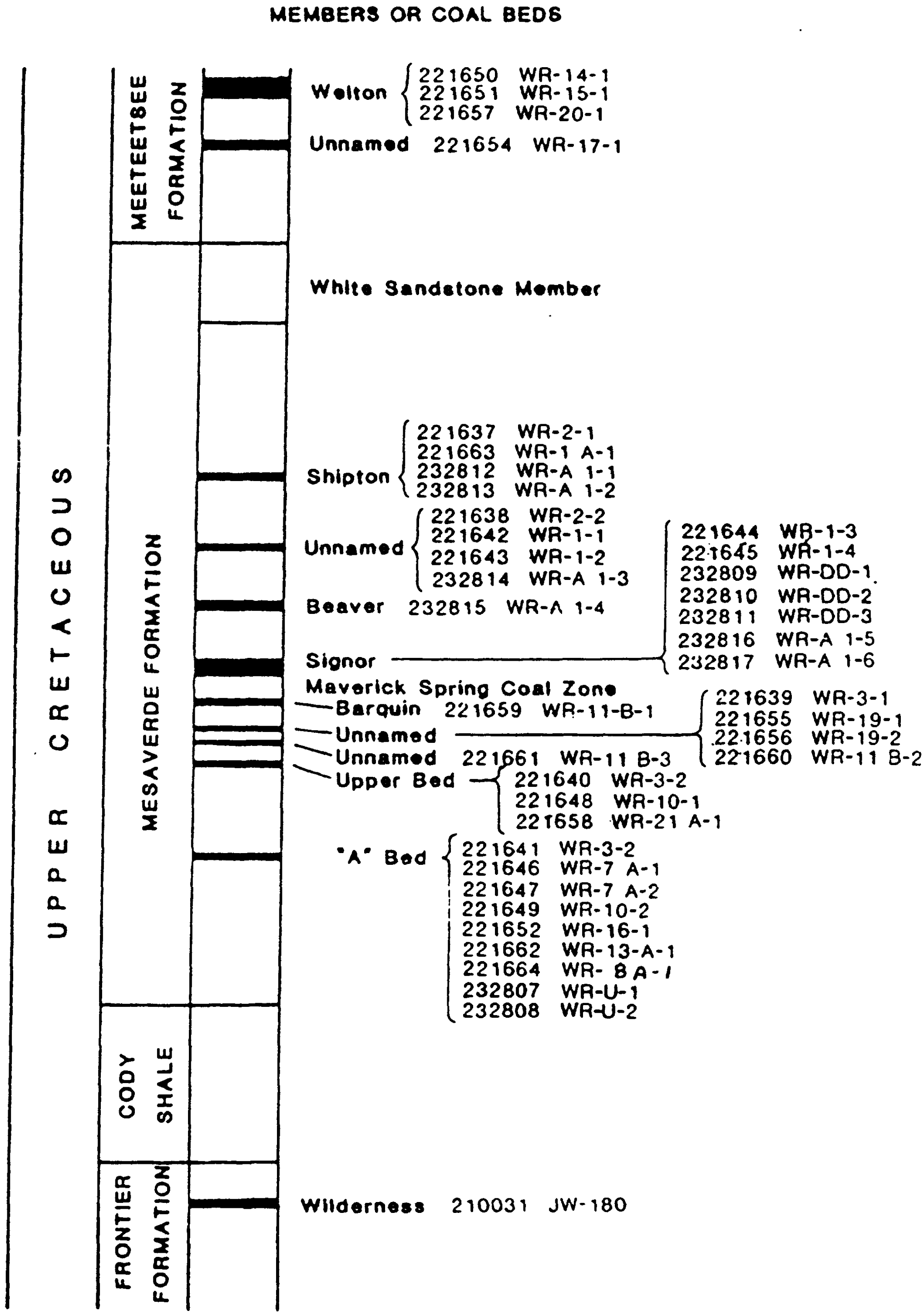

Figure 6
STRATIGRAPHIC LOCATIONS OF COAL SAMPLES

Table 1.--Descriptions and locations for 40 coal samples from Wind River Basin, Fremont County, Wyoming. Sample number is laboratory sample number.

Sample no.	Field no.	State	Latitude	Longitude	Formation	Coal	Apparent Rank	Sample type	Sampled thickness (inches)
w210031	JW-180	Wyoming	432610n	1092222w	Frontier	Wilderness	Subbit C	Channel	35.0
d221637	WR-2-1	Wyoming	425450n	1081127w	Mesaverde	Shipton	Subbit B	Drill Core	84.0
d221638	WR-2-2	Wyoming	425450n	1081127w	Mesaverde	Unnamed	Subbit B	Drill Core	42.0
d221639	WR-3-1	Wyoming	425507n	1083553w	Mesaverde	MS Zone	Subbit B	Drill Core	24.0
d221640	WR-3-2	Wyoming	425507n	1083553w	Mesaverde	MS Zone Upper	Subbit B	Drill Core	78.0
d221641	WR-5-1	Wyoming	425628n	1083609w	Mesaverde	MS Zone "A"	Subbit A	Drill Core	33.0
d221642	WR-1-1	Wyoming	425426n	1080946w	Mesaverde	Unnamed Upper Split	Subbit B	Drill Core	23.0
d221643	WR-1-2	Wyoming	425426n	1080946w	Mesaverde	Unnamed Lower Split	Subbit B	Drill Core	26.0
d221644	WR-1-3	Wyoming	425426n	1080946w	Mesaverde	Signor Upper Split	Subbit B	Drill Core	62.0
d221645	WR-1-4	Wyoming	425426n	1080946w	Mesaverde	Signor Lower Split	Subbit B	Drill Core	115.0
d221646	WR-7A-1	Wyoming	431449n	1085002w	Mesaverde	MS Zone Upper	Bitum C	Drill Core	51.0
d221647	WR-7A-2	Wyoming	431449n	1085002w	Mesaverde	MS Zone "A"	Bitum C	Drill Core	36.0
d221648	WR-10-1	Wyoming	432753n	1090226w	Mesaverde	MS Zone Upper	Bitum C	Drill Core	37.0
d221649	WR-10-2	Wyoming	432753n	1090226w	Mesaverde	MS Zone "A"	Bitum C	Drill Core	36.0
d221650	WR-14-1	Wyoming	432849n	1084710w	Meeteetse	Welton	Subbit A	Drill Core	126.0
d221651	WR-15-1	Wyoming	433008n	1084714w	Meeteetse	Welton	Subbit A	Drill Core	88.0
d221652	WR-16-1	Wyoming	432938n	1084354w	Mesaverde	MS Zone "A"	Subbit A	Drill Core	18.0
d221653	WR-16-2	Wyoming	432938n	1084354w	Mesaverde	MS Zone "A"	Subbit A	Drill Core	19.0
d221654	WR-17-1	Wyoming	432424n	1084723w	Meeteetse	Unnamed	Subbit A	Drill Core	30.0
d221655	WR-19-1	Wyoming	432829n	1083613w	Mesaverde	MS Zone Unnamed	Subbit A	Drill Core	20.0
d221656	WR-19-2	Wyoming	432829n	1083613w	Mesaverde	MS Zone Unnamed	Subbit A	Drill Core	19.0
d221657	WR-20-1	Wyoming	432816n	1083358w	Meeteetse	Welton(?)	Subbit A	Drill Core	51.0
d221658	WR-21A-1	Wyoming	432728n	1083704w	Mesaverde	MS Zone Upper	Subbit B	Drill Core	68.0
d221659	WR-11B-1	Wyoming	432222n	1084715w	Mesaverde	MS Zone Barquin	Bitum C	Drill Core	42.0
d221660	WR-11B-2	Wyoming	432222n	1084715w	Mesaverde	MS Zone Unnamed	Bitum C	Drill Core	33.0
d221661	WR-11B-3	Wyoming	432222n	1084715w	Mesaverde	MS Zone Unnamed	Bitum C	Drill Core	28.0
d221662	WR-13A-1	Wyoming	432950n	1084823w	Mesaverde	MS Zone "A"	Bitum C	Drill Core	35.0
d221663	WR-1A-1	Wyoming	425446n	1080944w	Mesaverde	Shipton	Subbit B	Drill Core	43.0
d221664	WR-8A-1	Wyoming	431711n	1085247w	Mesaverde	MS Zone "A"	Bitum C	Drill Core	30.0
d232807	WR-U-1	Wyoming	432420n	1085400w	Mesaverde	MS Zone "A"	Bitum C	Drill Core	28.8
d232808	WR-U-2	Wyoming	432420n	1085400w	Mesaverde	MS Zone "A"	Bitum C	Drill Core	38.4
d232809	WR-DD-1	Wyoming	424900n	1081130w	Mesaverde	Signor	Subbit C	Drill Core	78.0
d232810	WR-DD-2	Wyoming	424900n	1081130w	Mesaverde	Signor	Subbit C	Drill Core	288.0
d232811	WR-DD-3	Wyoming	424900n	1081130w	Mesaverde	Signor	Subbit C	Drill Core	36.0
d232812	WR-A1-1	Wyoming	425438n	1081120w	Mesaverde	Shipton	Subbit B	Drill Core	19.2

Table 1.--Descriptions and locations for 40 coal samples from Wind River Basin, Fremont County, Wyoming. Sample number is laboratory sample number.

Sample no.	Field no.	State	Latitude	Longitude	Formation	Coal	Apparent Rank	Sample type	Sampled thickness (inches)
d232813	WR-A1-2	Wyoming	425438n	1081120w	Mesaverde	Shipton	Subbit A	Drill Core	20.4
d232814	WR-A1-3	Wyoming	425438n	1081120w	Mesaverde	Unnamed	Subbit A	Drill Core	12.0
d232815	WR-A1-4	Wyoming	425438n	1081120w	Mesaverde	Beaver	Subbit A	Drill Core	28.8
d232816	WR-A1-5	Wyoming	425438n	1081120w	Mesaverde	Signor Upper Split	Subbit A	Drill Core	21.6
d232817	WR-A1-6	Wyoming	425438n	1081120w	Mesaverde	Signor Lower Split	Subbit A	Drill Core	12.0

Chemical analysis of the samples were made by two laboratories: 1) the U.S. Geological Survey (USGS) laboratories determined major-, minor-, and trace-elements data (table 2); and 2) the U.S. Department of Energy laboratories determined proximate and ultimate analyses, the forms-of-sulfur, the heats of combustion, the ash-fusion temperatures, and the free-swelling indices (table 3) and figs. 7 and 8. Methods of sample collecting and details of some analytical procedures have been described by Swanson and Huffman (1976), and the procedures and methods of interpretation of data have been described by Zubovic and others (1980).

Laboratory sample numbers, estimated apparent rank, sample type, and sample thickness are shown in table 1. The Parr Formula (American Society for Testing and Materials [ASTM], 1981), was used for calculating the apparent rank because ASTM criteria concerning the manner of collecting samples were not followed. However, the rank of the coal samples using the Parr formula are as follows: 4 subbituminous C, 11 subbituminous B, 14 subbituminous A, and 11 of high-volatile bituminous C rank. The high-volatile bituminous C coals are the result of intense deformation in the Crowheart NE, Maverick Spring, Lookout Butte, Lookout Butte SW, Shotgun Butte, Eagle Point, and Bargee quadrangles in the northwest part of the basin (fig. 9). The apparent high rank of coal in deeper parts of the basin is caused by depth of burial. This is substantiated by comparison with coal having similar depths of burial for which data indicate a high rank. Twenty-nine, or 73 percent of the 40 samples, are subbituminous A, B, and C rank. A coal-chip sample from the Welton(?) coal bed 6,600 feet deep in the Tom Brown Well No. 20-23 (T.4 N.-R.3 E., section 20), had a vitrinite reflectance index of 0.66 percent indicating a rank of high volatile bituminous B. (Ronald Stanton, USGS, personal communication).

Discussion of analytical data

Statistical summaries for the analytical data of the 40 coal samples are shown in tables 4, 5, and 6; detailed analytical data for all samples are shown in tables 2, 3, and 7.

The geometric means of the analytical data of the 40 coal samples have been statistically compared with 183 subbituminous coal samples from other localities in the United States on table 6 (Swanson and others, 1976, p. 16-19). Comparison of the arithmetic or geometric means shows a close relationship between the 40 coal samples from the Wind River Basin and the 183 U.S. samples.

Table 3 contains the data for the proximate and ultimate analyses on an as-received basis. Comparison of the geometric means of these data with the geometric means of 105 U.S. samples of subbituminous coal (Swanson and others, 1976, p. 17) shown in table 5 shows that the mean values for volatile matter, fixed carbon, hydrogen, carbon, and heat of combustion are about the same for the Wind River Basin and for the other U.S. samples. The mean values of the Wind River Basin samples for moisture, oxygen, and pyritic sulfur are 11-37 percent lower and the sulfate is more than 50 percent lower than the value for the U.S. subbituminous coal samples. In contrast, the mean values of ash, nitrogen, and organic sulfur in the Wind River samples are 20-50 percent, 15-30 percent, and more than 50 percent higher, respectively, than the same components in the subbituminous coals of the United States.

Table 2.--Major-, minor-, and trace- element concentration of 40 subbituminous coal samples from the Wind River Basin, Fremont County, Wyoming, reported on whole-coal basis.

[Values in percent or parts-per-million. 22 elements are from direct determinations on whole coal; all other elements calculated from analyses of ash. S means analysis by emission spectography; L, less than the value shown; H, interference for an element which cannot be resolved by any routine method; B, not determined; G, greater than. Sample number is laboratory sample number.]

Sample number	Si (percent)	Al (percent)	Ca (percent)	Mg (percent)	Na (percent)	K (percent)	Fe (percent)	Ti (percent)	Ag-S (ppm)	As (ppm)	Sample number
w210031	1.7	0.62	0.29	0.23	0.40	0.053	0.52	0.041	0.027	33	w210031
d221637	2.1	1.4	.52	.18	.023	.058	1.4	.072	.12L	40	d221637
d221638	2.2	.43	.55	.15	.011	.083	2.1	.028	.11L	5.7	d221638
d221639	2.2	1.3	.39	.10	.30	.083	.27	.066	.097L	1.1	d221639
d221640	1.3	.72	.47	.079	.32	.023	.18	.034	.066L	.72	d221640
d221641	3.9	2.1	.56	.17	.27	.12	.44	.12	.16L	.70	d221641
d221642	4.4	.98	.46	.23	.015	.25	.64	.057	.15L	3.4	d221642
d221643	1.2	.50	.46	.20	.008	.023	1.1	.021	.079L	13	d221643
d221644	1.8	.69	.55	.19	.035	.087	.20	.045	.080L	1.9	d221644
d221645	.42	.22	.54	.16	.054	.011	.54	.012	.045L	6.0	d221645
d221646	3.8	1.8	.31	.068	.15	.083	.18	.13	.13L	5.1	d221646
d221647	1.7	1.1	.37	.056	.14	.031	.34	.097	.081L	1.8	d221647
d221648	3.1	2.6	.98	.11	.081	.038	.33	.21	.15L	.93	d221648
d221649	2.3	1.9	.24	.049	.077	.021	.38	.12	.10L	2.8	d221649
d221650	3.8	1.5	1.6	.26	.12	.085	.38	.074	.16L	.79	d221650
d221651	5.0	1.9	1.2	.26	.018	.12	.38	.093	.18L	1.2	d221651
d221652	7.1	3.3	.60	.23	.047	.15	.52	.27	.25L	2.4	d221652
d221653	3.9	2.4	.61	.24	.048	.082	.29	.19	.16L	B	d221653
d221654	1.7	1.1	.50	.087	.18	.025	.29	.026	.080L	1.3	d221654
d221655	2.4	.60	.78	.37	.032	.095	.49	.039	.10L	10	d221655
d221656	2.2	1.4	.63	.29	.036	.069	.30	.052	.11L	2.4	d221656
d221657	3.2	1.1	.88	.15	.015	.011	.32	.072	.12L	4.2	d221657
d221658	.92	.30	.46	.17	.071	.025	.12	.018	.047L	1.3	d221658
d221659	6.1	1.3	.22	.060	.14	.073	.36	.092	.17L	17	d221659
d221660	2.3	1.3	.24	.048	.15	.032	.52	.067	.095L	34	d221660
d221661	1.8	.91	.24	.047	.14	.030	.54	.11	.076L	37	d221661
d221662	2.3	1.6	.47	.17	.056	.027	.60	.17	.11L	1.4	d221662
d221663	1.6	1.3	.54	.22	.17	.020	.17	.090	.086L	4.1	d221663
d221664	2.8	2.0	.40	.065	.15	.027	.52	.23	.12L	2.2	d221664
d232807	4.1	1.5	.33	.071	.061	.13	1.2	.078	B	12	d232807
d232808	H	H	H	H	H	H	H	H	B	25	d232808
d232809	H	H	H	H	H	H	H	H	B	18	d232809
d232810	3.5	1.1	.79	.18	.34	.18	1.8	.053	B	21	d232810
d232811	2.8	.48	.80	.13	.19	.028	1.0	.025	B	3.3	d232811
d232812	5.0	2.5	.25	.13	.023	.18	.25	.12	B	1.4	d232812
d232813	9.6	2.3	.22	.19	.032L	.44	.35	.097	B	1.6	d232813
d232814	.23	.13	.21	.092	.016	.006	.088	.009	B	1.2	d232814
d232815	2.2	.74	.22	.098	.014	.083	.25	.034	B	3.4	d232815
d232816	1.2	1.0	.32	.080	.059	.024	.19	.054	B	5.1	d232816
d232817	.90	.41	.24	.066	.082	.031	.085	.024	B	1.1	d232817

Table 2.--Major-, minor-, and trace- element concentration of 40 subbituminous coal samples from the Wind River Basin, Fremont County, Wyoming, reported on whole-coal basis--continued

Sample number	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Ce (ppm)	Cl (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)	Sample number
w210031	45	31	1	0.17	9.0	210	1.9	6.3	0.6	5.3	w210031
d221637	100	55	1	.13	B	100	.9	4.8	B	8.3	d221637
d221638	110	610	3	.12L	B	100L	.9	5.3	B	3.2	d221638
d221639	130	610	1	.42	B	100L	1.4	7.4	B	38	d221639
d221640	130	600		.07L	B	100L	.8	3.1	B	4.0	d221640
d221641	170	560	1	.17L	B	100L	1.1	8.0	B	8.2	d221641
d221642	100	620	4	.16L	B	100L	1.2	10	B	5.4	d221642
d221643	100	71	6	.09	B	100L	2.0	5.1	B	3.4	d221643
d221644	100	710	2	.09L	B	100L	.8	5.2	B	4.9	d221644
d221645	93	64	1	.05L	B	100L	.5	2.8	B	2.7	d221645
d221646	85	320	2	.28	B	100L	2.1	6.6	B	9.6	d221646
d221647	110	430	1	.09L	B	100L	1.2	4.5	B	8.5	d221647
d221648	80	230	1	.16L	B	100L	1.6	6.4	B	11	d221648
d221649	68	130	2	.11L	B	100L	2.9	4.2	B	17	d221649
d221650	55	330	1	.17L	B	100L	1.2	7.7	B	12	d221650
d221651	82	320	1	.20L	B	100L	2.3	14	B	12	d221651
d221652	130	960	3	.27L	B	100L	3.4	21	B	25	d221652
d221653	160	950	4	.17L	B	100L	1.5	6.0	B	9.5	d221653
d221654	82	240	1	.09	B	100L	2.8	4.1	B	6.1	d221654
d221655	170	540	2	.11	B	100L	1.4	7.8	B	4.9	d221655
d221656	160	390	1	.12	B	100L	2.3	4.9	B	6.3	d221656
d221657	61	440		.13L	B	100L	1.0	7.5	B	11	d221657
d221658	170	450	1	.10	B	100L	1.4	2.1	B	2.4	d221658
d221659	85	450	2	.18L	B	100L	1.1	7.8	B	7.6	d221659
d221660	110	530	2	.10L	B	100L	1.2	5.2	B	9.4	d221660
d221661	120	420	1	.08L	B	100L	1.0	5.2	B	11	d221661
d221662	150	270	2	.12L	B	100L	1.8	6.1	B	11	d221662
d221663	110	240	4	.09L	B	100L	.7	2.4	B	3.0	d221663
d221664	100	580	1	.13L	B	100L	.9	6.3	B	13	d221664
d232807	B	B	B	B	B	200L	3.3	13	B	B	d232807
d232808	B	B	B	B	B	200L	1.1	3.8	B	B	d232808
d232809	B	B	B	B	B	200L	.8	2.0	B	B	d232809
d232810	B	B	B	B	B	200L	5.5	14	B	B	d232810
d232811	B	B	B	B	B	200L	1.5	3.0	B	B	d232811
d232812	B	B	B	B	B	200L	1.7	9.5	B	B	d232812
d232813	B	B	B	B	B	200L	2.0	21	B	B	d232813
d232814	B	B	B	B	B	200L	.7	1.1	B	B	d232814
d232815	B	B	B	B	B	200L	.9	5.4	B	B	d232815
d232816	B	B	B	B	B	200L	.9	5.5	B	B	d232816
d232817	B	B	B	B	B	200L	.8	6.2	B	B	d232817

Table 2.--Major-, minor-, and trace- element concentration of 40 subbituminous coal samples from the Wind River Basin, Fremont County, Wyoming, reported on whole-coal basis--continued

Sample number	Eu (ppm)	F (ppm)	Ga-S (ppm)	Gd-S (ppm)	Ge-S (ppm)	Hf (ppm)	Hg (ppm)	La (ppm)	Li (ppm)	Lu (ppm)	Sample number
w210031	0.18	50	3.4	1.3L	11	0.5	0.080	4	2.3	0.1	w210031
d221637	B	55	3.3	2.6L	.80	B	.37	B	7.2	B	d221637
d221638	B	40	5.6	2.4L	1.8	B	.17	B	3.9	B	d221638
d221639	B	60	2.6	2.1L	.74	B	.070	B	24	B	d221639
d221640	B	40	1.6	1.4L	.26	B	.050	B	6.9	B	d221640
d221641	B	75	3.4	3.4L	.70	B	.050	B	34	B	d221641
d221642	B	100	2.3	3.3L	3.9	B	.10	B	6.2	B	d221642
d221643	B	40	3.8	1.7L	15	B	.35	B	3.1	B	d221643
d221644	B	65	2.7	1.7L	1.7	B	.050	B	7.5	B	d221644
d221645	B	20L	1.0	.98L	.69	B	.35	B	.7	B	d221645
d221646	B	40	3.9	2.8L	1.2	B	.050	B	15	B	d221646
d221647	B	95	2.5	1.8L	1.5	B	.11	B	18	B	d221647
d221648	B	90	4.8	3.3L	.67	B	.070	B	62	B	d221648
d221649	B	70	4.8	2.2L	1.9	B	.16	B	33	B	d221649
d221650	B	45	2.6	3.4L	.52	B	.050	B	10	B	d221650
d221651	B	50	3.4	4.0L	.82	B	.060	B	18	B	d221651
d221652	B	90	6.3	5.5L	1.9	B	.11	B	47	B	d221652
d221653	B	40	5.4	4.7	1.5	B	.060	B	24	B	d221653
d221654	B	30	1.8	1.7L	2.0	B	.020	B	6.7	B	d221654
d221655	B	55	3.1	2.2L	7.1	B	.13	B	4.6	B	d221655
d221656	B	60	2.9	2.3L	.69	B	.18	B	15	B	d221656
d221657	B	25	1.5	2.5L	.32	B	.12	B	9.8	B	d221657
d221658	B	35	1.0	1.0L	.29	B	.020	B	1.6	B	d221658
d221659	B	45	2.5	3.6L	.81	B	.13	B	9.9	B	d221659
d221660	B	35	4.4	2.1L	3.7	B	.60	B	19	B	d221660
d221661	B	20	4.1	1.7L	1.3	B	.73	B	10	B	d221661
d221662	B	25	6.0	2.5L	3.3	B	.37	B	22	B	d221662
d221663	B	65	5.2	1.9L	2.9	B	.090	B	8.6	B	d221663
d221664	B	95	5.2	2.7L	.84	B	.17	B	43	B	d221664
d232807	B	180	B	B	B	B	B	B	B	B	d232807
d232808	B	20	B	B	B	B	B	B	B	B	d232808
d232809	B	35	B	B	B	B	B	B	B	B	d232809
d232810	B	120	B	B	B	B	B	B	B	B	d232810
d232811	B	40	B	B	B	B	B	B	B	B	d232811
d232812	B	140	B	B	B	B	B	B	B	B	d232812
d232813	B	210	B	B	B	B	B	B	B	B	d232813
d232814	B	20	B	B	B	B	B	B	B	B	d232814
d232815	B	65	B	B	B	B	B	B	B	B	d232815
d232816	B	180	B	B	B	B	B	B	B	B	d232816
d232817	B	30	B	B	B	B	B	B	B	B	d232817

Table 2.--Major-, minor-, and trace- element concentration of 40 subbituminous coal samples from the Wind River Basin, Fremont County, Wyoming, reported on whole-coal basis--continued

Sample number	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Nd-S (ppm)	Ni-S (ppm)	P (ppm)	Pb (ppm)	Sb (ppm)	Sc (ppm)	Se (ppm)	Sample number
w210031	3.9	1.6	0.98	4.6	6.3	44L	2.0	0.70	1.5	1.4	w210031
d221637	14	.54	4.6	12L	2.1	44	6.4	.64	B	2.7	d221637
d221638	40	2.7	4.4	11L	4.9	44L	3.1L	1.1	B	1.2	d221638
d221639	4.5	.32	2.4	9.8L	7.0	87	4.5	1.6	B	1.5	d221639
d221640	5.0	.35	2.6	6.7L	3.2	390	2.3	.38	B	1.4	d221640
d221641	12	.38	5.1	16L	2.6	430	4.3L	.58	B	2.0	d221641
d221642	34	1.2	4.6	15L	5.6	130	4.1L	.65	B	1.1	d221642
d221643	15	.60	1.9	8.0L	8.6	440	2.5	.62	B	1.0	d221643
d221644	13	.37	3.0	8.1L	3.5	610	2.2L	.63	B	1.3	d221644
d221645	21	.78	1.0	4.6L	2.0	44	1.9	.29	B	2.6	d221645
d221646	12	.53	4.7	13L	3.6	44L	6.3	1.1	B	2.4	d221646
d221647	19	.47	4.0	8.2L	2.6	1,000	3.9	.81	B	1.3	d221647
d221648	31	.74	10	15L	4.8	920	8.5	.32	B	2.2	d221648
d221649	17	1.0	7.3	10L	4.3	520	6.2	.74	B	2.1	d221649
d221650	53	.79	5.3	16L	3.6	44	7.1	.50	B	.9	d221650
d221651	68	.98	6.6	19L	7.0	44	9.0	.65	B	1.4	d221651
d221652	36	1.1	10	25L	9.9	48	11	1.3	B	3.1	d221652
d221653	15	.56	10	16L	5.6	87	7.1	2.4	B	1.4	d221653
d221654	67	1.1	2.3	8.1L	5.2	87	3.0	1.7	B	.8	d221654
d221655	76	.73	5.2	10L	6.5	87	3.0	2.4	B	1.4	d221655
d221656	14	1.1	5.8	11L	6.6	520	4.8	1.1	B	1.6	d221656
d221657	18	1.2	3.8	12L	2.3	44	5.1	.39	B	1.2	d221657
d221658	6.6	.28	1.3	4.7L	3.6	220	1.9	.37	B	.7	d221658
d221659	8.6	.79	5.4	17L	4.1	48	5.8	.94	B	1.3	d221659
d221660	7.5	1.1	9.0	9.6L	6.8	44	5.0	5.0	B	2.2	d221660
d221661	5.4	1.0	4.4	7.7L	3.0	44	3.0	1.4	B	2.4	d221661
d221662	22	.92	8.6	11L	3.1	44	3.4	.69	B	2.2	d221662
d221663	21	.44	6.9	10	4.3	44L	6.4	1.0	B	B	d221663
d221664	20	.74	7.0	12L	3.2	830	7.1	.73	B	3.1	d221664
d232807	24L	B	B	B	B	1,100	B	1.7	B	2.2	d232807
d232808	H	B	B	B	B	220	B	.14	B	2.2	d232808
d232809	H	B	B	B	B	390	B	.54	B	1.1	d232809
d232810	28L	B	B	B	B	87L	B	1.9	B	2.6	d232810
d232811	29	B	B	B	B	92	B	.43	B	1.3	d232811
d232812	30L	B	B	B	B	140	B	.38	B	1.6	d232812
d232813	44L	B	B	B	B	87L	B	1.7	B	2.7	d232813
d232814	4.1	B	B	B	B	87L	B	.45	B	.8	d232814
d232815	31	B	B	B	B	350	B	.50	B	2.5	d232815
d232816	15	B	B	B	B	1,900	B	.37	B	1.4	d232816
d232817	22	B	B	B	B	87L	B	.25	B	1.2	d232817

Table 2.--Major-, minor-, and trace- element concentration of 40 subbituminous coal samples from the Wind River Basin, Fremont County, Wyoming, reported on whole-coal basis--continued

Sample number	Sm (ppm)	Sn-S (ppm)	Sr-S (ppm)	Ta-S (ppm)	Tb (ppm)	Th (ppm)	U (ppm)	V-S (ppm)	W-S (ppm)	Y-S (ppm)	Sample number
w210031	0.90	0.80	36	0.02	0.20	2.4	1.5	7.7	0.09	1.6	w210031
d221637	B	1.2L	41	130L	B	2.7	1.5	16	12L	9.3	d221637
d221638	B	1.1L	20	120L	B	.82	.80	13	11L	11	d221638
d221639	B	.98L	290	110L	B	1.3	1.8	29	9.8L	17	d221639
d221640	B	.67L	490	72L	B	1.1	1.3	7.9	6.7L	5.1	d221640
d221641	B	1.6L	430	170L	B	2.8	1.5	14	16L	12	d221641
d221642	B	1.5L	66	160L	B	1.5	1.7	18	15L	12	d221642
d221643	B	.80L	150	86L	B	.59	.78	7.8	8.0L	17	d221643
d221644	B	.81L	350G	87L	B	1.2	1.4	13	8.1L	6.8	d221644
d221645	B	.46L	110	49L	B	.32	.64	4.0	4.6L	2.3	d221645
d221646	B	1.3L	120	140L	B	2.8	1.6	26	13L	14	d221646
d221647	B	.82L	320	88L	B	1.8	1.1	20	8.2L	13	d221647
d221648	B	1.5L	340	160L	B	3.8	1.7	41	15L	13	d221648
d221649	B	1.0L	180	110L	B	2.0	1.6	37	10L	14	d221649
d221650	B	1.6L	310	170L	B	2.6	1.5	21	16L	7.9	d221650
d221651	B	1.9L	400	200L	B	3.7	2.3	28	19L	12	d221651
d221652	B	2.5L	790	270L	B	3.5	2.5	60	25L	27	d221652
d221653	B	1.6L	340	170L	B	3.8	1.9	32	16L	22	d221653
d221654	B	.81L	230	87L	B	1.3	.93	13	8.1L	7.4	d221654
d221655	B	1.0L	180	110L	B	1.0	1.4	26	10L	9.9	d221655
d221656	B	1.1L	260	120L	B	1.9	2.4	20	11L	10	d221656
d221657	B	1.2L	120	130L	B	1.7	1.5	18	12L	7.6	d221657
d221658	B	.47L	150	51L	B	.45	.22L	4.2	4.7L	5.6	d221658
d221659	B	1.7L	85	180L	B	3.3	1.0	25	17L	15	d221659
d221660	B	.96L	130	100L	B	2.2	1.8	21	9.6L	9.0	d221660
d221661	B	.77L	120	83L	B	1.1	1.0	24	7.7L	8.3	d221661
d221662	B	1.1L	160	120L	B	3.2	1.4	42	11L	15	d221662
d221663	B	.87L	230	94L	B	3.1	1.2	14	8.7L	16	d221663
d221664	B	1.2L	500	130L	B	4.2	1.5	31	12L	12	d221664
d232807	B	B	B	B	B	2.8	2.4	B	B	B	d232807
d232808	B	B	B	B	B	.95	.49	B	B	B	d232808
d232809	B	B	B	B	B	.71	.51	B	B	B	d232809
d232810	B	B	B	B	B	1.9	2.3	B	B	B	d232810
d232811	B	B	B	B	B	.84	.66	B	B	B	d232811
d232812	B	B	B	B	B	3.7	2.4	B	B	B	d232812
d232813	B	B	B	B	B	3.3	5.3	B	B	B	d232813
d232814	B	B	B	B	B	.25	.49	B	B	B	d232814
d232815	B	B	B	B	B	1.0	1.9	B	B	B	d232815
d232816	B	B	B	B	B	1.9	.84	B	B	B	d232816
d232817	B	B	B	B	B	.61	.77	B	B	B	d232817

Table 2.--Major-, minor-, and trace- element concentration of 40 subbituminous coal samples from the Wind River Basin, Fremont County, Wyoming, reported on whole-coal basis--continued

Sample number	Yb (ppm)	Zn (ppm)	Zr-S (ppm)
w210031	0.6	9.8	8.9
d221637	B	18	200
d221638	B	7.7	88
d221639	B	19	47
d221640	B	2.4	35
d221641	B	7.5	120
d221642	B	26	69
d221643	B	50	40
d221644	B	7.9	54
d221645	B	3.5	15
d221646	B	9.5	170
d221647	B	7.2	64
d221648	B	9.2	200
d221649	B	17	120
d221650	B	6.2	91
d221651	B	12	130
d221652	B	30	380
d221653	B	19	290
d221654	B	3.2	48
d221655	B	13	200
d221656	B	14	68
d221657	B	2.5L	80
d221658	B	1.7	23
d221659	B	8.5	320
d221660	B	6.3	130
d221661	B	3.2	120
d221662	B	16	330
d221663	B	10	390
d221664	B	7.6	96
d232807	B	B	B
d232808	B	B	B
d232809	B	B	B
d232810	B	B	B
d232811	B	B	B
d232812	B	B	B
d232813	B	B	B
d232814	B	B	B
d232815	B	B	B
d232816	B	B	B
d232817	B	B	B

Table 3.--Proximate and ultimate analyses. Heat content, forms of sulfur, free-swelling index, and ash-fusion temperature determinations for 40 subbituminous coal samples from Wind River Basin, Fremont County, Wyoming.

[All anlyses except Kcal/kg, Btu, free-swelling index and ash-fusion temperatures in percent. For each sample number, the analyses are reported three ways: first, as received, second, moisture-free, and third, moisture- and ash-free. Analyses by Coal Analysis Section, Department of Energy, Pittsburgh, Pa. and a commercial testing laboratory following ASTM standards. G for ash-fusion temperatures means greater than 1540 C. Sample number inTable are laboratory sample numbers.]

	Proximate Analysis				Ultimate Analysis					Heat of Combustion	
Sample number	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
w210031	22.1	31.9	39.1	6.9	5.1	49.4	1.1	36.7	0.8	4,420	7,960
	---	40.9	50.2	8.9	3.4	63.4	1.4	21.9	1.0	5,680	10,220
	---	44.9	55.1	---	3.7	69.6	1.5	24.0	1.1	6,230	11,210
d221637	23.4	31.0	34.3	11.3	6.1	48.5	1.0	31.4	1.7	4,730	8,510
	---	40.5	44.8	14.8	4.6	63.3	1.3	13.8	2.2	6,170	11,110
	---	47.5	52.5	---	5.4	74.3	1.5	16.2	2.6	7,240	13,030
d221638	25.1	30.2	33.1	11.6	5.9	47.0	1.3	31.3	3.0	4,640	8,360
	---	40.3	44.2	15.5	4.2	62.8	1.7	12.0	4.0	6,200	11,160
	---	47.7	52.3	---	4.9	74.2	2.1	14.2	4.7	7,340	13,200
d221639	18.1	33.0	39.6	9.3	5.6	54.3	1.6	28.6	.6	5,200	9,370
	---	40.3	48.4	11.4	4.4	66.3	2.0	15.3	.7	6,350	11,430
	---	45.5	54.5	---	4.9	74.8	2.2	17.2	.8	7,170	12,900
d221640	19.4	31.8	42.3	6.5	5.9	56.0	1.5	29.6	.5	5,350	9,630
	---	39.5	52.5	8.1	4.6	69.5	1.9	15.3	.6	6,640	11,940
	---	42.9	57.1	---	5.1	75.6	2.0	16.7	.7	7,220	12,990
d221641	16.8	31.4	35.4	16.4	5.4	50.0	1.4	26.0	.8	4,830	8,700
	---	37.7	42.5	19.7	4.2	60.1	1.7	13.3	1.0	5,810	10,460
	---	47.0	53.0	---	5.3	74.9	2.1	16.6	1.2	7,240	13,030
d221642	20.5	30.2	33.8	15.5	5.6	47.6	1.3	28.6	1.3	4,630	8,340
	---	38.0	42.5	19.5	4.2	59.9	1.6	13.1	1.6	5,830	10,490
	---	47.2	52.8	---	5.2	74.4	2.0	16.2	2.0	7,240	13,030
d221643	23.1	32.5	36.8	7.6	6.1	50.9	1.4	32.2	1.8	4,950	8,900
	---	42.3	47.9	9.9	4.6	66.2	1.8	15.2	2.3	6,430	11,580
	---	46.9	53.1	---	5.1	73.4	2.0	16.8	2.6	7,140	12,850
d221644	22.4	32.8	36.3	8.5	6.2	52.0	1.5	31.1	.7	5,080	9,140
	---	42.3	46.8	11.0	4.8	67.0	1.9	14.4	.9	6,540	11,780
	---	47.5	52.5	---	5.4	75.3	2.2	16.2	1.0	7,350	13,230
d221645	23.9	31.8	40.1	4.2	6.4	54.2	1.6	32.6	1.0	5,270	9,490
	---	41.8	52.7	5.5	4.9	71.2	2.1	14.9	1.3	6,930	12,470
	---	44.2	55.8	---	5.2	75.4	2.2	15.8	1.4	7,330	13,200
d221646	11.5	34.1	40.6	13.8	5.6	57.2	1.6	21.2	.6	5,640	10,150
	---	38.5	45.9	15.6	4.9	64.6	1.8	12.4	.7	6,370	11,470
	---	45.6	54.4	---	5.8	76.6	2.1	14.7	.8	7,550	13,590

Table ? .--Proximate and ultimate analyses. Heat content, forms of sulfur, free-swelling index, and ash-fusion temperature determinations for 40 subbituminous coal samples from Wind River Basin, Fremont County, Wyoming--continued

Sample number	Air-dried loss	Forms of sulfur: Sulfate	Forms of sulfur: Pyritic	Forms of sulfur: Organic	Free swelling index	Ash fusion temperature, C: Initial deformation	Ash fusion temperature, C: Softening	Ash fusion temperature, C: Fluid
w210031	16.8	0.14	0.03	0.58	0.0	1,150	1,215	1,290
	---	.18	.04	.74				
	---	.20	.04	.82				
d221637	.0	.01	1.16	.51	.0	1,120	1,190	1,230
	---	.01	1.51	.67				
	---	.02	1.78	.78				
d221638	.0	.01	2.49	.51	.0	1,025	1,095	1,145
	---	.01	3.32	.68				
	---	.02	3.93	.81				
d221639	.0	.01	.03	.53	.0	1,225	1,300	1,360
	---	.01	.04	.65				
	---	.01	.04	.73				
d221640	.0	.01	.02	.43	.0	1,040	1,120	1,200
	---	.01	.02	.53				
	---	.01	.03	.58				
d221641	.0	.01	.20	.55	.0	1,245	1,300	1,365
	---	.01	.24	.66				
	---	.01	.30	.82				
d221642	.0	.01	.50	.82	.0	1,180	1,245	1,315
	---	.01	.63	1.03				
	---	.02	.78	1.28				
d221643	.0	.02	.95	.84	.0	1,065	1,105	1,160
	---	.03	1.24	1.09				
	---	.03	1.37	1.21				
d221644	.0	.01	.08	.61	.0	1,115	1,175	1,240
	---	.01	.10	.79				
	---	.01	.12	.88				
d221645	.0	.01	.50	.50	.0	1,095	1,160	1,195
	---	.01	.66	.66				
	---	.01	.70	.70				
d221646	.0	.01	.07	.49	.0	1,460	1,505	1,540
	---	.01	.08	.55				
	---	.01	.09	.66				

Table 3.--Proximate and ultimate analyses. Heat content, forms of sulfur, free-swelling index, and ash-fusion temperature determinations for 40 subbituminous coal samples from Wind River Basin, Fremont County, Wyoming--continued

Sample number	Proximate Analysis				Ultimate Analysis					Heat of Combustion	
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
d221647	11.9	35.5	43.5	9.1	5.8	60.6	1.8	21.7	1.0	6,000	10,790
	---	40.3	49.4	10.3	5.1	68.8	2.0	12.6	1.1	6,810	12,250
	---	44.9	55.1	---	5.7	76.7	2.3	14.1	1.3	7,590	13,660
d221648	7.1	36.5	41.4	15.0	5.3	60.4	1.5	17.2	.7	5,960	10,720
	---	39.3	44.6	16.1	4.9	65.0	1.6	11.7	.8	6,410	11,540
	---	46.9	53.1	---	5.8	77.5	1.9	14.0	.9	7,650	13,770
d221649	9.6	37.0	43.5	9.9	5.6	62.8	1.6	19.3	.9	6,210	11,180
	---	40.9	48.1	11.0	5.0	69.5	1.8	11.9	1.0	6,870	12,370
	---	46.0	54.0	---	5.6	78.0	2.0	13.4	1.1	7,720	13,890
d221650	11.9	30.9	41.4	15.8	5.1	55.2	1.3	22.2	.3	5,280	9,510
	---	35.1	47.0	17.9	4.3	62.7	1.5	13.2	.3	6,000	10,790
	---	42.7	57.3	---	5.2	76.3	1.8	16.1	.4	7,310	13,150
d221651	10.4	31.1	39.6	18.9	4.9	53.4	1.2	21.1	.4	5,080	9,140
	---	34.7	44.2	21.1	4.2	59.6	1.3	13.2	.4	5,670	10,200
	---	44.0	56.0	---	5.3	75.5	1.7	16.8	.6	7,180	12,920
d221652	12.1	32.3	29.7	25.9	4.8	46.1	.9	21.5	.8	4,540	8,160
	---	36.7	33.8	29.5	3.9	52.4	1.0	12.2	.9	5,160	9,290
	---	52.1	47.9	---	5.6	74.4	1.5	17.3	1.3	7,310	13,170
d221653	14.0	33.3	35.2	17.5	4.9	51.2	1.2	24.7	.6	4,990	8,990
	---	38.7	40.9	20.3	3.9	59.5	1.4	14.3	.7	5,810	10,450
	---	48.6	51.4	---	4.9	74.7	1.8	17.9	.9	7,290	13,120
d221654	15.6	31.6	44.5	8.3	5.4	58.7	1.2	25.9	.6	5,640	10,150
	---	37.4	52.7	9.8	4.3	69.5	1.4	14.3	.7	6,680	12,020
	---	41.5	58.5	---	4.8	77.1	1.6	15.8	.8	7,410	13,340
d221655	15.2	37.4	37.1	10.3	5.5	56.3	1.2	25.8	.9	5,440	9,790
	---	44.1	43.7	12.1	4.5	66.4	1.4	14.5	1.1	6,410	11,540
	---	50.2	49.8	---	5.1	75.6	1.6	16.5	1.2	7,300	13,140
d221656	14.4	34.0	40.2	11.4	5.4	55.8	1.2	25.4	.8	5,390	9,700
	---	39.7	47.0	13.3	4.4	65.2	1.4	14.7	.9	6,290	11,330
	---	45.8	54.2	---	5.1	75.2	1.6	17.0	1.1	7,260	13,070
d221657	16.6	30.5	41.4	11.5	5.0	54.7	1.0	27.1	.6	5,200	9,360
	---	36.6	49.6	13.8	3.8	65.6	1.2	14.8	.7	6,230	11,220
	---	42.4	57.6	---	4.4	76.1	1.4	17.2	.8	7,230	13,020
d221658	20.2	32.7	42.7	4.4	5.9	57.2	1.2	30.8	.5	5,500	9,890
	---	41.0	53.5	5.5	4.6	71.7	1.5	16.1	.6	6,890	12,400
	---	43.4	56.6	---	4.8	75.9	1.6	17.0	.7	7,290	13,120

Table 3.--Proximate and ultimate analyses. Heat content, forms of sulfur, free-swelling index, and ash-fusion temperature determinations for 40 subbituminous coal samples from Wind River Basin, Fremont County, Wyoming--continued

Sample number	Air-dried loss	Forms of sulfur: Sulfate	Pyritic	Organic	Free swelling index	Ash fusion temperature, C: Initial deformation	Softening	Fluid
d221647	0.0	0.01	0.29	0.74	0.0	1,240	1,280	1,345
	---	.01	.33	.84				
	---	.01	.37	.94				
d221648	.0	.01	.10	.55	.0	1,415	1,460	1,510
	---	.01	.11	.59				
	---	.01	.13	.71				
d221649	.0	.01	.24	.64	1.0	1,540	1,540G	1,540G
	---	.01	.27	.71				
	---	.01	.30	.80				
d221650	.0	.01	.07	.27	.0	1,170	1,230	1,295
	---	.01	.08	.31				
	---	.01	.10	.37				
d221651	.0	.01	.07	.34	.0	1,245	1,290	1,350
	---	.01	.08	.38				
	---	.01	.10	.48				
d221652	.0	.01	.32	.45	.0	1,470	1,540	1,540G
	---	.01	.36	.51				
	---	.02	.52	.73				
d221653	.0	.01	.20	.38	.0	1,450	1,525	1,540
	---	.01	.23	.44				
	---	.01	.29	.55				
d221654	.0	.01	.17	.41	.0	1,250	1,295	1,355
	---	.01	.20	.49				
	---	.01	.22	.54				
d221655	.0	.01	.40	.53	.0	1,125	1,165	1,205
	---	.01	.47	.62				
	---	.01	.54	.71				
d221656	.0	.02	.34	.46	.0	1,250	1,290	1,330
	---	.02	.40	.54				
	---	.03	.46	.62				
d221657	.0	.01	.18	.46	.0	1,200	,245	1,305
	---	.01	.22	.55				
	---	.01	.25	.64				
d221658	.0	.01	.04	.46	.0	1,065	1,110	1,155
	---	.01	.05	.58				
	---	.01	.05	.61				

Table [illegible].--Proximate and ultimate analyses. Heat content, forms of sulfur, free-swelling index, and ash-fusion temperature determinations for 40 subbituminous coal samples from Wind River Basin, Fremont County, Wyoming--continued

Sample number	Proximate Analysis: Moisture	Volatile matter	Fixed carbon	Ash	Ultimate Analysis: Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Heat of Combustion: Kcal/kg	Btu/lb
d221659	10.6	30.7	40.0	18.7	4.9	54.2	1.2	20.3	0.7	5,300	9,530
	---	34.3	44.7	20.9	4.2	60.6	1.3	12.2	.8	5,920	10,660
	---	43.4	56.6	---	5.3	76.7	1.7	15.4	1.0	7,490	13,480
d221660	12.1	34.7	44.1	9.1	5.4	60.9	1.2	22.4	.9	5,980	10,760
	---	39.5	50.2	10.4	4.6	69.3	1.4	13.2	1.0	6,800	12,240
	---	44.0	56.0	---	5.1	77.3	1.5	14.8	1.1	7,580	13,650
d221661	11.2	35.5	45.7	7.6	5.5	62.6	1.4	21.9	1.1	6,180	11,120
	---	40.0	51.5	8.6	4.8	70.5	1.6	13.5	1.2	6,950	12,520
	---	43.7	56.3	---	5.2	77.1	1.7	14.7	1.4	7,610	13,690
d221662	12.3	36.5	40.4	10.8	5.9	58.4	1.3	22.3	1.3	5,800	10,450
	---	41.6	46.1	12.3	5.2	66.6	1.5	13.0	1.5	6,620	11,910
	---	47.5	52.5	---	5.9	75.9	1.7	14.8	1.7	7,550	13,590
d221663	20.2	33.5	37.6	8.7	5.4	53.4	1.2	30.7	.6	5,190	9,340
	---	42.0	47.1	10.9	4.0	66.9	1.5	16.0	.8	6,500	11,710
	---	47.1	52.9	---	4.4	75.1	1.7	17.9	.8	7,300	13,140
d221664	10.0	34.4	42.6	13.0	5.2	58.9	1.3	20.3	1.2	5,850	10,530
	---	38.2	47.3	14.4	4.5	65.4	1.4	12.7	1.3	6,500	11,700
	---	44.7	55.3	---	5.3	76.5	1.7	14.8	1.6	7,600	13,680
d232807	8.5	37.8	42.3	11.4	5.6	62.1	1.3	18.3	1.4	6,120	11,010
	---	41.3	46.3	12.4	5.0	67.8	1.4	11.8	1.5	6,690	12,030
	---	47.2	52.8	---	5.7	77.4	1.6	13.4	1.7	7,630	13,740
d232808	10.0	35.9	47.8	6.3	5.5	64.7	1.4	19.9	2.2	6,370	11,470
	---	39.9	53.1	7.0	4.9	71.9	1.5	12.2	2.4	7,080	12,750
	---	42.9	57.1	---	5.3	77.3	1.6	13.2	2.6	7,610	13,700
d232809	31.4	30.2	29.0	9.4	6.5	42.7	1.0	38.1	2.4	4,120	7,420
	---	44.0	42.3	13.6	4.4	62.2	1.4	14.8	3.5	6,010	10,810
	---	51.0	49.0	---	5.1	72.1	1.7	17.1	4.1	6,960	12,520
d232810	29.9	31.8	28.4	10.0	6.4	43.4	.9	37.3	1.9	4,200	7,560
	---	45.3	40.4	14.2	4.5	61.9	1.3	15.4	2.7	5,990	10,780
	---	52.9	47.1	---	5.2	72.2	1.5	17.9	3.1	6,980	12,570
d232811	30.9	29.3	28.5	11.3	6.3	42.4	1.0	38.2	.7	4,030	7,260
	---	42.4	41.2	16.4	4.2	61.3	1.5	15.6	1.1	5,830	10,500
	---	50.7	49.3	---	5.0	73.3	1.8	18.6	1.3	6,970	12,550
d232812	18.8	28.4	38.7	14.0	5.6	50.0	1.1	28.6	.7	4,880	8,780
	---	35.0	47.7	17.3	4.3	61.5	1.3	14.6	.9	6,010	10,820
	---	42.3	57.7	---	5.3	74.4	1.6	17.7	1.0	7,270	13,080

Table 3.--Proximate and ultimate analyses. Heat content, forms of sulfur, free-swelling index, and ash-fusion temperature determinations for 40 subbituminous coal samples from Wind River Basin, Fremont County, Wyoming--continued

Sample number	Air-dried loss	Forms of sulfur: Sulfate	Forms of sulfur: Pyritic	Forms of sulfur: Organic	Free swelling index	Ash fusion temperature, C: Initial deformation	Ash fusion temperature, C: Softening	Ash fusion temperature, C: Fluid
d221659	0.0	0.01	0.25	0.47	0.0	1,430	1,505	1,540
	---	.01	.28	.53				
	---	.01	.35	.66				
d221660	.0	.01	.24	.64	.0	1,325	1,390	1,455
	---	.01	.27	.73				
	---	.01	.30	.81				
d221661	.0	.01	.40	.67	.0	1,050	1,120	1,190
	---	.01	.45	.75				
	---	.01	.49	.83				
d221662	.0	.01	.66	.67	.0	1,225	1,270	1,320
	---	.01	.75	.76				
	---	.01	.86	.87				
d221663	.0	.01	.11	.53	.0	1,265	1,315	1,360
	---	.01	.14	.66				
	---	.01	.15	.75				
d221664	.0	.01	.41	.73	.0	1,375	1,425	1,480
	---	.01	.46	.81				
	---	.01	.53	.95				
d232807	4.8	.06	.75	.59	.50	1,215	1,280	1,345
	---	.07	.82	.64				
	---	.07	.94	.74				
d232808	6.7	.10	1.54	.56	.50	1,105	1,140	1,165
	---	.11	1.71	.62				
	---	.12	1.84	.67				
d232809	26.6	.27	1.47	.69	.0	1,305	1,365	1,380
	---	.39	2.14	1.01				
	---	.46	2.48	1.16				
d232810	25.1	.35	1.04	.50	.0	1,095	1,155	1,190
	---	.50	1.48	.71				
	---	.58	1.73	.83				
d232811	26.1	.04	.24	.46	.0	1,175	1,260	1,340
	---	.06	.35	.67				
	---	.07	.42	.80				
d232812	15.8	.05	.10	.55	.0	1,470	1,540	1,540G
	---	.06	.12	.68				
	---	.07	.15	.82				

Table 3.--Proximate and ultimate analyses. Heat content, forms of sulfur, free-swelling index, and ash-fusion temperature determinations for 40 subbituminous coal samples from Wind River Basin, Fremont County, Wyoming--continued

	Proximate Analysis				Ultimate Analysis					Heat of Combustion	
Sample number	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
d232813	15.6	25.9	32.9	25.7	5.0	43.9	1.0	23.5	0.9	4,280	7,700
	---	30.6	39.0	30.4	3.9	52.0	1.2	11.4	1.0	5,070	9,120
	---	44.0	56.0	---	5.6	74.8	1.8	16.4	1.5	7,280	13,110
d232814	20.1	32.7	45.3	1.8	6.4	59.4	1.2	30.4	.7	5,790	10,420
	---	41.0	56.7	2.3	5.3	74.4	1.5	15.7	.9	7,240	13,040
	---	41.9	58.1	---	5.4	76.1	1.6	16.1	.9	7,410	13,340
d232815	15.4	31.6	45.3	7.6	5.8	58.4	1.2	25.5	1.4	5,780	10,410
	---	37.4	53.6	9.0	4.8	69.1	1.4	14.0	1.7	6,840	12,310
	---	41.1	58.9	---	5.3	75.9	1.5	15.3	1.9	7,510	13,530
d232816	15.1	32.9	42.8	9.2	5.7	57.0	1.4	25.7	1.0	5,590	10,060
	---	38.8	50.4	10.9	4.7	67.2	1.6	14.5	1.2	6,590	11,850
	---	43.5	56.5	---	5.3	75.4	1.8	16.2	1.3	7,390	13,300
d232817	14.9	32.6	47.2	5.2	5.8	61.9	1.3	25.1	.7	6,010	10,810
	---	38.4	55.5	6.2	4.8	72.7	1.6	13.9	.8	7,060	12,710
	---	40.9	59.1	---	5.2	77.5	1.7	14.8	.9	7,520	13,540

Table [illegible].--Proximate and ultimate analyses. Heat content, forms of sulfur, free-swelling index, and ash-fusion temperature determinations for 40 subbituminous coal samples from Wind River Basin, Fremont County, Wyoming--continued

Sample number	Air-dried loss	Forms of sulfur: Sulfate	Pyritic	Organic	Free swelling index	Ash fusion temperature, C: Initial deformation	Softening	Fluid
d232813	12.8	0.05	0.11	0.72	0.0	1,455	1,490	1,505
	---	.06	.13	.85				
	---	.09	.19	1.23				
d232814	16.8	.04	.03	.61	.0	1,160	1,195	1,225
	---	.05	.04	.76				
	---	.05	.04	.78				
d232815	12.3	.08	.64	.72	.0	1,195	1,250	1,295
	---	.09	.76	.85				
	---	.10	.83	.94				
d232816	11.1	.13	.28	.57	.0	1,275	1,330	1,360
	---	.15	.33	.67				
	---	.17	.37	.75				
d232817	11.4	.03	.05	.61	.0	1,225	1,275	1,325
	---	.04	.06	.72				
	---	.04	.06	.76				

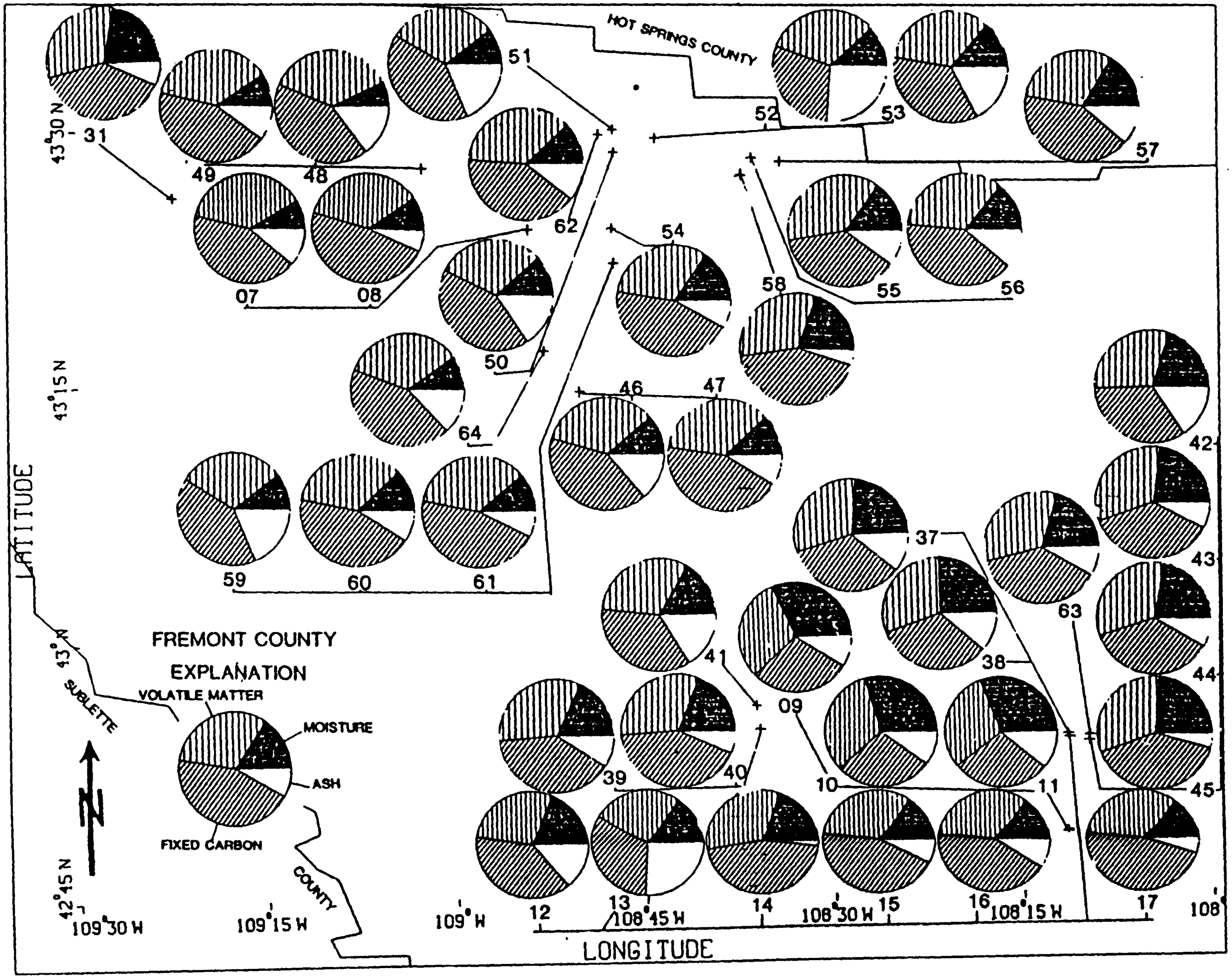

Figure 7. - Computer plot showing location of drill-core holes and outcrop, sample distribution, pie diagram of proximate analysis, and last two digits of laboratory identification number

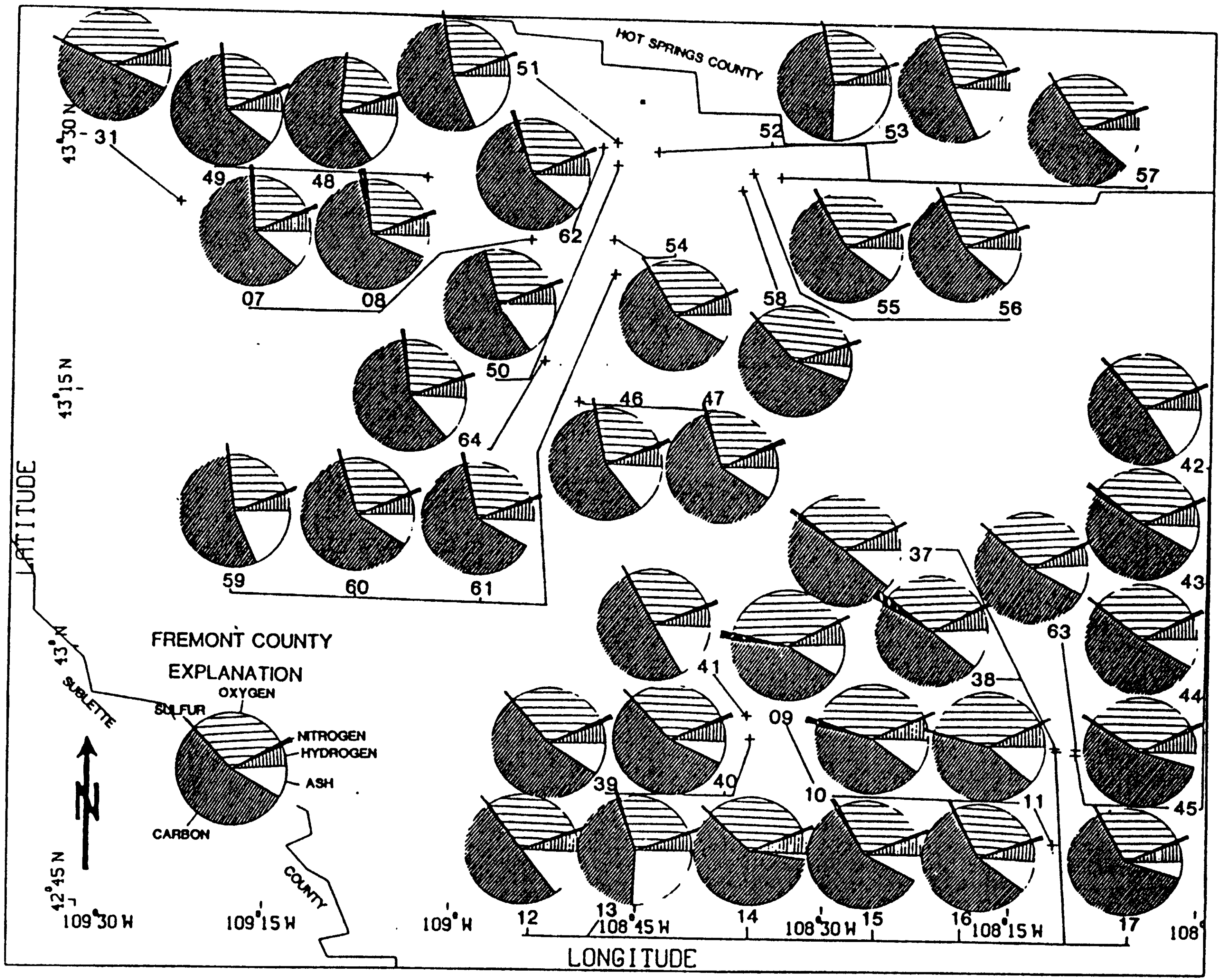

Figure 8. - Computer plot showing location of drill-core hole and outcrop, sample distribution, pie diagram of ultimate analysis, and last two digits of laboratory identification number.

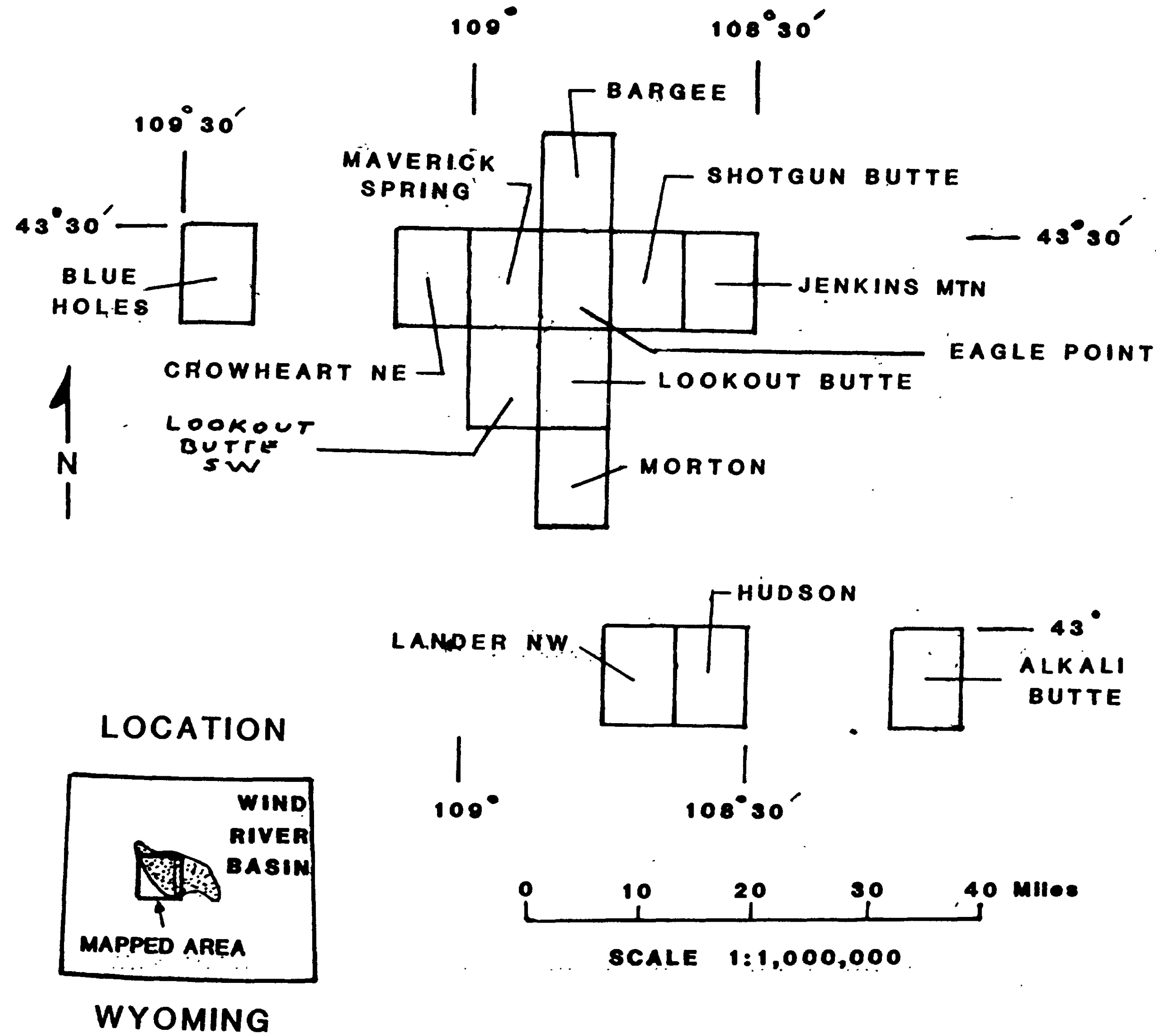

Figure 9 LOCATION OF GEOLOGIC MAPPING IN TWELVE 7.5 MINUTE QUADRANGLES IN THE WIND RIVER BASIN, WYOMING

Table 4. Arithmetic mean, observed range, geometric mean, and geometric deviation of ash content and contents of 10 major and minor oxides in the laboratory ash of 40 coal samples from the Wind River Basin and geometric means of ash and oxide contents for 183 U.S. subbituminous coal samples.

[All samples ashed at 525°C; all analyses in percent]

Oxide	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Geometric mean of 183 U.S. samples (Swanson and others, 1976, p. 19)
		Minimum	Maximum			
(Ash).........	12.4	4.9	27.4	11.5	1.46	10.8
SiO_2........	45	18	73	44	1.3	37
Al_2O_3.....	19	6.6	32	18	1.5	16
CaO...........	6.5	1.1	15	5.6	1.8	13
MgO...........	2.3	.55	7	1.9	1.9	3.1
Na_2O........	1.4	.12	6.1	.82	3.2	1.4
K_2O.........	.66	.1	1.9	.54	1.9	.60
Fe_2O_3.....	6.4	1.7	24	5	2	7.2
MnO...........	.03	.01	.1	.02	1.9	.06
TiO_2........	1.1	.32	2.8	.92	1.7	.82
P_2O_5......	.79	.04	5.9	.35	3.8	--

Table 5. Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, heat of combustion, forms of sulfur, and ash-fusion temperature of 40 coal samples from the Wind River Basin and geometric mean of these characteristics for 105 U.S. subbituminous coal samples.

[All values are reported on the as-received basis]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Geometric mean of 105 U.S. samples (Swanson and others, 1976, p. 18)
		Minimum	Maximum			
Proximate and ultimate analyses, in weight percent						
Moisture	16.8	7.1	31.4	15.8	1.4	18.4
Volatile matter	32.7	25.9	37.8	32.6	1.1	33.8
Fixed carbon	39.3	28.4	47.8	38.9	1.2	39.0
Ash	11.2	1.8	25.9	10.1	1.6	8.8
Hydrogen	5.6	4.8	6.5	5.6	1.1	5.9
Carbon	54.4	42.4	64.7	54	1.1	54.3
Nitrogen	1.3	.9	1.8	1.3	1.2	1.0
Oxygen	26.5	17.2	38.2	26	1.2	29.3
Sulfur	1.0	.3	3	.9	1.6	.7
Heat of combustion in Btu/lb (kcal/kgc 0.556 Btu/lb)						
Btu/lb	9,513	7,256	11,472	9,446	1.1	9,410
Forms of sulfur						
Sulfate	0.04	0.01	0.35	0.02	2.8	.04
Pyritic	.42	.02	2.49	.22	3.3	.35
Organic	.56	.27	.84	.54	1.3	.32
Ash-fusion temperature in ^{o}F ($^{o}C = 5/9\ ^{o}F - 32$)						
Initial deformation	2,259	1,880	2,800	2,246	1.1	
Softening temperature	2,357	2,000	2,800	2,345	1.1	
Fluid temperature	2,440	2,090	2,800	2,429	1.1	

Table 6. Arithmetic mean, observed range, geometric mean, and geometric deviation of contents of 26 elements in 40 coal samples from Wind River Basin and geometric means of the contents of these elements for 183 U.S. subbituminous coal samples.

[All analyses are in parts per million and are reported on a whole-coal basis]

Element	Arithmetic mean	Observed range Minimum	Observed range Maximum	Geometric mean	Geometric deviation	Geometric mean of 183 U.S. samples (Swanson and others, 1976, p. 16)
As..........	8.4	0.7	40	3.9	3.4	3
B...........	110	45	170	100	1.4	70
Ba..........	420	31	960	320	2.3	300
Be..........	1.8	.39	5.9	1.4	2.0	.7
Co..........	1.6	.51	5.5	1.4	1.7	2
Cr..........	6.8	1.1	21	5.7	1.6	7
Cu..........	9.4	2.4	38	7.6	1.9	10
F...........	66	20	210	55	1.8	63
Ga..........	3.5	.97	6.3	3.1	1.6	3
Ge..........	2.4	.26	15	1.4	2.7	--
Hg..........	.17	.02	0.73	.11	2.4	.12
Li..........	16	.69	62	11	2.9	7
Mn..........	23	3.9	76	17	2.2	--
Mo..........	.84	.28	2.7	.74	1.7	1.5
Nb..........	5.1	.98	11	4	1.9	5
Ni..........	4.7	2	9.9	4.3	1.5	5
Pb..........	5.1	1.9	11	4.5	1.7	5
Sb..........	.98	.14	5	.75	2	.7
Se..........	1.7	.71	3.1	1.6	1.5	1.3
Sr..........	240	20	790	180	2.3	100
Th..........	2	.25	4.2	1.6	2	--
U...........	1.5	.48	5.3	1.3	1.7	1.3
V...........	22	4	60	19	1.9	15
Y...........	12	1.6	27	10	1.8	5
Zn..........	12	1.7	50	9.4	2.1	19
Zr..........	140	8.9	390	94	2.5	20

Table 7.--Major- and minor- oxides and trace-element concentrations in the laboratory ash of 40 subbituminous coal samples from the Wind River Basin, Fremont County, Wyoming.

[Values in percent or parts-per-million. Coal ashed at 525 C. L means less than the value shown; H, interference for an element which cannot be resolved any routine method; G greater than; B, not determined; S, after element title indicates determinations by automatic plate reading computer assisted, emission spectographic analyses. The standard deviation of any single answer should be taken as plus 50% and minus 35%. Sample number is laboratory number.]

Sample number	Ash (percent)	SiO2 (percent)	Al2O3 (percent)	CaO (percent)	MgO (percent)	Na2O (percent)	K2O (percent)	Fe2O3 (percent)	TiO2 (percent)	P2O5 (percent)	Sample number
w210031	8.9	42	13	4.6	4.3	6.1	0.71	8.4	0.77	0.11L	w210031
d221637	13.1	34	21	5.6	2.3	.24	.53	16	.92	.08	d221637
d221638	12.2	39	6.6	6.3	2.0	.12	.82	24	.38	.08L	d221638
d221639	10.5	45	23	5.2	1.7	3.9	.95	3.7	1.1	.19	d221639
d221640	7.2	39	19	9.1	1.8	6.1	.38	3.6	.78	1.3	d221640
d221641	17.1	49	23	4.6	1.6	2.2	.86	3.7	1.2	.58	d221641
d221642	16.4	58	11	3.9	2.3	.12	1.8	5.6	.58	.18	d221642
d221643	8.6	30	11	7.6	3.8	.12	.32	19	.40	1.2	d221643
d221644	8.7	45	15	8.8	3.6	.54	1.2	3.3	.87	1.6	d221644
d221645	4.9	18	8.3	15	5.3	1.5	.28	16	.42	.20	d221645
d221646	13.9	58	25	3.1	.81	1.5	.72	1.9	1.6	.07L	d221646
d221647	8.8	41	25	5.9	1.1	2.2	.42	5.6	1.8	2.7	d221647
d221648	16.4	41	30	8.4	1.2	.67	.28	2.9	2.2	1.3	d221648
d221649	11.1	45	32	3.1	.73	.94	.23	4.9	1.8	1.1	d221649
d221650	17.2	47	17	13	2.5	.92	.59	3.2	.72	.06	d221650
d221651	20.0	54	18	8.5	2.2	.12	.71	2.7	.78	.05	d221651
d221652	27.4	56	23	3.1	1.4	.23	.64	2.7	1.7	.04	d221652
d221653	16.9	49	26	5.0	2.4	.38	.58	2.4	1.8	.12	d221653
d221654	8.7	43	25	8.1	1.7	2.8	.35	4.7	.50	.23	d221654
d221655	11.2	45	10	9.8	5.5	.38	1.0	6.3	.58	.18	d221655
d221656	11.5	41	23	7.7	4.2	.42	.72	3.7	.75	1.0	d221656
d221657	12.7	54	16	9.7	2.0	.16	.10	3.6	.95	.08	d221657
d221658	5.1	39	11	13	5.6	1.9	.59	3.3	.58	.98	d221658
d221659	18.0	73	14	1.7	.55	1.1	.49	2.9	.85	.06	d221659
d221660	10.3	47	25	3.2	.78	2.0	.37	7.3	1.1	.10	d221660
d221661	8.3	47	21	4.1	.95	2.3	.43	9.3	2.2	.12	d221661
d221662	12.3	41	25	5.3	2.3	.61	.26	7.0	2.3	.08	d221662
d221663	9.4	36	26	8.0	3.8	2.4	.26	2.6	1.6	.11L	d221663
d221664	13.4	45	28	4.2	.80	1.5	.24	5.6	2.8	1.4	d221664
d232807	15.6	56	18	3.0	.76	.53	1.0	11	.84	1.7	d232807
d232808	6.8	H	H	H	H	H	H	H	H	.74	d232808
d232809	10.9	H	H	H	H	H	H	H	H	.83	d232809
d232810	17.8	42	12	6.2	1.7	2.6	1.2	14	.50	.11L	d232810
d232811	12.9	47	7.0	8.7	1.7	2.0	.26	12	.32	.16	d232811
d232812	19.1	56	25	1.9	1.1	.16	1.1	1.9	1.1	.16	d232812
d232813	28.5	72	16	1.1	1.1	.15L	1.9	1.7	.57	.07L	d232813
d232814	2.2	23	11	13	7.0	.96	.32	5.7	.65	.91L	d232814
d232815	8.4	57	17	3.6	1.9	.22	1.2	4.3	.67	.95	d232815
d232816	7.5	34	26	6.0	1.8	1.1	.38	3.6	1.2	5.9	d232816
d232817	4.5	43	17	7.3	2.5	2.5	.83	2.7	.89	.44L	d232817

Table 7.--Major- and minor- oxides and trace-element concentrations in the laboratory ash of 40 subbituminous coal samples from the Wind River Basin, Fremont County, Wyoming--continued

Sample number	SO3 (percent)	Ag-S (ppm)	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Sample number
w210031	11	0.30	500	350	7.0	1.9	100	21	71	6.7	w210031
d221637	B	.92L	770	420	10	1.0	B	6.6	37	B	d221637
d221638	B	.92L	880	5,000	28	1.0L	B	7.5	43	B	d221638
d221639	B	.92L	1,200	5,800	13	4.0	B	13	70	B	d221639
d221640	B	.92L	1,800	8,300	6.5	1.0L	B	11	43	B	d221640
d221641	B	.92L	970	3,300	6.1	1.0L	B	6.4	47	B	d221641
d221642	B	.92L	620	3,800	26	1.0L	B	7.3	61	B	d221642
d221643	B	.92L	1,200	830	68	1.0	B	23	59	B	d221643
d221644	B	.92L	1,200	8,200	20	1.0L	B	8.9	60	B	d221644
d221645	B	.92L	1,900	1,300	12	1.0L	B	10	57	B	d221645
d221646	B	.92L	610	2,300	12	2.0	B	15	47	B	d221646
d221647	B	.92L	1,200	4,900	13	1.0L	B	14	51	B	d221647
d221648	B	.92L	490	1,400	4.8	1.0L	B	9.8	39	B	d221648
d221649	B	.92L	610	1,200	18	1.0L	B	26	38	B	d221649
d221650	B	.92L	320	1,900	3.2	1.0L	B	7.0	45	B	d221650
d221651	B	.92L	410	1,600	5.8	1.0L	B	12	70	B	d221651
d221652	B	.92L	480	3,500	12	1.0L	B	12	77	B	d221652
d221653	B	.92L	940	5,600	21	1.0L	B	8.9	36	B	d221653
d221654	B	.92L	940	2,800	7.7	1.0	B	32	47	B	d221654
d221655	B	.92L	1,500	4,800	22	1.0	B	13	70	B	d221655
d221656	B	.92L	1,400	3,400	6.8	1.0	B	20	43	B	d221656
d221657	B	.92L	480	3,500	3.1	1.0L	B	7.7	59	B	d221657
d221658	B	.92L	3,400	8,800	15	2.0	B	27	41	B	d221658
d221659	B	.92L	470	2,500	8.9	1.0L	B	6.1	43	B	d221659
d221660	B	.92L	1,100	5,100	19	1.0L	B	12	50	B	d221660
d221661	B	.92L	1,400	5,000	16	1.0L	B	12	63	B	d221661
d221662	B	.92L	1,200	2,200	15	1.0L	B	15	50	B	d221662
d221663	B	.92L	1,200	2,500	40	1.0L	B	7.9	26	B	d221663
d221664	B	.92L	760	4,300	10	1.0L	B	6.7	47	B	d221664
d232807	B	B	B	B	B	B	B	21	86	B	d232807
d232808	B	B	B	B	B	B	B	16	56	B	d232808
d232809	B	B	B	B	B	B	B	7.1	18	B	d232809
d232810	B	B	B	B	B	B	B	31	78	B	d232810
d232811	B	B	B	B	B	B	B	12	23	B	d232811
d232812	B	B	B	B	B	B	B	8.6	50	B	d232812
d232813	B	B	B	B	B	B	B	7.0	74	B	d232813
d232814	B	B	B	B	B	B	B	34	50	B	d232814
d232815	B	B	B	B	B	B	B	10	64	B	d232815
d232816	B	B	B	B	B	B	B	11	73	B	d232816
d232817	B	B	B	B	B	B	B	18	140	B	d232817

Table 7.--Major- and minor- oxides and trace-element concentrations in the laboratory ash of 40 subbituminous coal samples from the Wind River Basin, Fremont County, Wyoming--continued

Sample number	Cu (ppm)	Eu (ppm)	Ga-S (ppm)	Gd-S (ppm)	Ge-S (ppm)	Hf (ppm)	La (ppm)	Li (ppm)	Lu (ppm)	Mn (ppm)	Sample number
w210031	59	2.0	38	15L	120	5.6	45	26	1.1	44	w210031
d221637	63	B	25	20L	6.1	B	B	55	B	110	d221637
d221638	26	B	46	20L	15	B	B	32	B	330	d221638
d221639	360	B	25	20L	7.0	B	B	230	B	43	d221639
d221640	56	B	22	20L	3.6	B	B	96	B	70	d221640
d221641	48	B	20	20L	4.1	B	B	200	B	72	d221641
d221642	33	B	14	20L	24	B	B	38	B	210	d221642
d221643	39	B	44	20L	170	B	B	36	B	180	d221643
d221644	56	B	31	20L	19	B	B	86	B	150	d221644
d221645	56	B	21	20L	14	B	B	14	B	420	d221645
d221646	69	B	28	20L	8.9	B	B	110	B	86	d221646
d221647	97	B	28	20L	17	B	B	210	B	220	d221647
d221648	66	B	29	20L	4.1	B	B	380	B	190	d221648
d221649	150	B	43	20L	17	B	B	300	B	150	d221649
d221650	72	B	15	20L	3.0	B	B	58	B	310	d221650
d221651	62	B	17	20L	4.1	B	B	88	B	340	d221651
d221652	91	B	23	20L	7.1	B	B	170	B	130	d221652
d221653	56	B	32	28	9.1	B	B	140	B	91	d221653
d221654	70	B	21	20L	23	B	B	77	B	770	d221654
d221655	44	B	28	20L	63	B	B	41	B	680	d221655
d221656	55	B	25	20L	6.0	B	B	130	B	120	d221656
d221657	86	B	12	20L	2.5	B	B	77	B	140	d221657
d221658	47	B	19	20L	5.6	B	B	32	B	130	d221658
d221659	42	B	14	20L	4.5	B	B	55	B	48	d221659
d221660	91	B	43	20L	36	B	B	180	B	73	d221660
d221661	130	B	49	20L	16	B	B	120	B	65	d221661
d221662	88	B	49	20L	27	B	B	180	B	180	d221662
d221663	32	B	55	20L	31	B	B	91	B	220	d221663
d221664	100	B	39	20L	6.3	B	B	320	B	150	d221664
d232807	B	B	B	B	B	B	B	B	B	160L	d232807
d232808	B	B	B	B	B	B	B	B	B	H	d232808
d232809	B	B	B	B	B	B	B	B	B	H	d232809
d232810	B	B	B	B	B	B	B	B	B	160L	d232810
d232811	B	B	B	B	B	B	B	B	B	230	d232811
d232812	B	B	B	B	B	B	B	B	B	160L	d232812
d232813	B	B	B	B	B	B	B	B	B	160L	d232813
d232814	B	B	B	B	B	B	B	B	B	190	d232814
d232815	B	B	B	B	B	B	B	B	B	370	d232815
d232816	B	B	B	B	B	B	B	B	B	200	d232816
d232817	B	B	B	B	B	B	B	B	B	500	d232817

Table 7.--Major- and minor- oxides and trace-element concentrations in the laboratory ash of 40 subbituminous coal samples from the Wind River Basin, Fremont County, Wyoming--continued

Sample number	Mo-S (ppm)	Nb-S (ppm)	Nd-S (ppm)	Ni-S (ppm)	Pb (ppm)	Sc (ppm)	Sm (ppm)	Sn-S (ppm)	Sr-S (ppm)	Ta (ppm)	Sample number
w210031	18	11	52	71	22	17	10	9.0	410	0.19	w210031
d221637	4.1	35	93L	16	49	B	B	9.3L	310	1,000L	d221637
d221638	22	36	93L	40	25L	B	B	9.3L	160	1,000L	d221638
d221639	3.0	23	93L	67	43	B	B	9.3L	2,800	1,000L	d221639
d221640	4.8	36	93L	45	32	B	B	9.3L	6,800	1,000L	d221640
d221641	2.2	30	93L	15	25L	B	B	9.3L	2,500	1,000L	d221641
d221642	7.2	28	93L	34	25L	B	B	9.3L	400	1,000L	d221642
d221643	7.0	22	93L	100	29	B	B	9.3L	1,800	1,000L	d221643
d221644	4.3	35	93L	40	25L	B	B	9.3L	4,000G	1,000L	d221644
d221645	16	21	93L	41	39	B	B	9.3L	2,300	1,000L	d221645
d221646	3.8	34	93L	26	45	B	B	9.3L	850	1,000L	d221646
d221647	5.3	45	93L	29	44	B	B	9.3L	3,600	1,000L	d221647
d221648	4.5	61	93L	29	52	B	B	9.3L	2,100	1,000L	d221648
d221649	9.0	66	93L	39	56	B	B	9.3L	1,600	1,000L	d221649
d221650	4.6	31	93L	21	41	B	B	9.3L	1,800	1,000L	d221650
d221651	4.9	33	93L	35	45	B	B	9.3L	2,000	1,000L	d221651
d221652	4.0	38	93L	36	41	B	B	9.3L	2,900	1,000L	d221652
d221653	3.3	62	93L	33	42	B	B	9.3L	2,000	1,000L	d221653
d221654	13	27	93L	60	35	B	B	9.3L	2,700	1,000L	d221654
d221655	6.5	46	93L	58	27	B	B	9.3L	1,600	1,000L	d221655
d221656	9.2	50	93L	57	42	B	B	9.3L	2,300	1,000L	d221656
d221657	9.6	30	93L	18	40	B	B	9.3L	920	1,000L	d221657
d221658	5.5	26	93L	71	37	B	B	9.3L	2,900	1,000L	d221658
d221659	4.4	30	93L	23	32	B	B	9.3L	470	1,000L	d221659
d221660	11	87	93L	66	49	B	B	9.3L	1,300	1,000L	d221660
d221661	12	53	93L	36	36	B	B	9.3L	1,400	1,000L	d221661
d221662	7.5	70	93L	25	28	B	B	9.3L	1,300	1,000L	d221662
d221663	4.7	73	110	46	68	B	B	9.3L	2,400	1,000L	d221663
d221664	5.5	52	93L	24	53	B	B	9.3L	3,700	1,000L	d221664
d232807	B	B	B	B	B	B	B	B	B	B	d232807
d232808	B	B	B	B	B	B	B	B	B	B	d232808
d232809	B	B	B	B	B	B	B	B	B	B	d232809
d232810	B	B	B	B	B	B	B	B	B	B	d232810
d232811	B	B	B	B	B	B	B	B	B	B	d232811
d232812	B	B	B	B	B	B	B	B	B	B	d232812
d232813	B	B	B	B	B	B	B	B	B	B	d232813
d232814	B	B	B	B	B	B	B	B	B	B	d232814
d232815	B	B	B	B	B	B	B	B	B	B	d232815
d232816	B	B	B	B	B	B	B	B	B	B	d232816
d232817	B	B	B	B	B	B	B	B	B	B	d232817

Table 7.--Major- and minor- oxides and trace-element concentrations in the laboratory ash of 40 subbituminous coal samples from the Wind River Basin, Fremont County, Wyoming--continued

Sample number	Tb (ppm)	Th (ppm)	U (ppm)	V-S (ppm)	W-S (ppm)	Y-S (ppm)	Yb (ppm)	Zn (ppm)	Zr-S (ppm)	Sample number
w210031	2.2	27	17	86	1.0	18	6.7	110	100	w210031
d221637	B	21	11	120	93L	71	B	140	1,500	d221637
d221638	B	6.7	6.6	110	93L	94	B	63	720	d221638
d221639	B	12	17	280	93L	160	B	180	450	d221639
d221640	B	15	18	110	93L	71	B	33	480	d221640
d221641	B	16	8.8	140	93L	72	B	44	710	d221641
d221642	B	9.1	10	110	93L	76	B	160	420	d221642
d221643	B	6.9	9.1	91	93L	200	B	580	460	d221643
d221644	B	14	16	150	93L	78	B	91	620	d221644
d221645	B	6.5	13	81	93L	47	B	71	300	d221645
d221646	B	20	12	190	93L	100	B	68	1,200	d221646
d221647	B	20	13	230	93L	150	B	82	730	d221647
d221648	B	23	10	250	93L	80	B	56	1,200	d221648
d221649	B	18	14	330	93L	130	B	150	1,100	d221649
d221650	B	15	8.7	120	93L	46	B	36	530	d221650
d221651	B	19	12	140	93L	62	B	59	650	d221651
d221652	B	13	9.1	220	93L	99	B	110	1,400	d221652
d221653	B	22	11	190	93L	130	B	110	1,700	d221653
d221654	B	15	11	150	93L	85	B	37	550	d221654
d221655	B	8.9	13	230	93L	88	B	120	1,800	d221655
d221656	B	17	21	170	93L	89	B	120	590	d221656
d221657	B	13	12	140	93L	60	B	20L	630	d221657
d221658	B	8.8	4.3L	82	93L	110	B	33	460	d221658
d221659	B	18	5.6	140	93L	83	B	47	1,800	d221659
d221660	B	21	17	200	93L	87	B	61	1,300	d221660
d221661	B	13	12	290	93L	100	B	39	1,400	d221661
d221662	B	26	11	340	93L	120	B	130	2,700	d221662
d221663	B	33	13	150	93L	170	B	110	4,100	d221663
d221664	B	31	11	230	93L	90	B	57	720	d221664
d232807	B	18	16	B	B	B	B	B	B	d232807
d232808	B	14	7.2	B	B	B	B	B	B	d232808
d232809	B	6.5	4.6	B	B	B	B	B	B	d232809
d232810	B	11	13	B	B	B	B	B	B	d232810
d232811	B	6.5	5.1	B	B	B	B	B	B	d232811
d232812	B	20	12	B	B	B	B	B	B	d232812
d232813	B	12	19	B	B	B	B	B	B	d232813
d232814	B	11	22	B	B	B	B	B	B	d232814
d232815	B	12	23	B	B	B	B	B	B	d232815
d232816	B	26	11	B	B	B	B	B	B	d232816
d232817	B	14	17	B	B	B	B	B	B	d232817

Table 8. Elements searched for but not found.

ag	os
au	pd
bi	pr
br	pt
cd	rb
ce	re
cs	rh
dy	ru
er	sc
eu	sm
gd	sn
hf	ta
ho	tb
in	te
ir	tl
la	tm
lu	w

Comparison in table 6 of the geometric means of the trace-element contents of 183 subbituminous samples (Swanson and others, 1976, p. 19) with the Wind River Basin samples indicates that data for eight of the elements in Wind River samples differ by less than 20 percent. In the Wind River Basin samples, As, B, Se, and V are 20-50 percent higher than in the U.S. samples; Be, Li, Sr, Y, and Zr are more than 50 percent higher, whereas Co, Cu, and Nb are 20-50 percent lower, and Mo and Zn are more than 50 percent lower. The geometric mean values for the elements As, F, Hg, Ni, Pb, Sb, and Se in the Wind River Basin coals are not significantly different from those in the 183 subbituminous coals (Swanson and others, 1976, p. 19). This suggests that the use of these coals would not create new environmental problems and could be used in plants that use other coals of similar rank. Table 8 lists elements searched for but not found.

Comparison in table 4 of the geometric means of the major- and minor-element oxides of the Wind River Basin samples with those of 183 U.S. subbituminous coal samples (Swanson and others, 1976, p. 18) indicates that the mean value of the ash, and SiO_2, Al_2O_3, TiO_2, and K_2O in ash are similar. The mean values for Fe_2O_3, Na_2O, and MgO are 20-50 percent lower, whereas the mean values for CaO and MnO are more than 50 percent lower than the means of the 183 subbituminous samples. Although the ash-fusion temperatures of the two sets of coal samples cannot be compared, the lower values for the alkali metals and ferrous iron in the ash of Wind River Basin coals suggest that ash of these coals should have higher average ash-fusion temperatures than do those of the 183 subbituminous coal samples. The Wind River coals therefore should have less tendency to foul boilers than other coals.

Figures 7 and 8 show the relative locations and a pie-diagram representation of the components identified in the proximate and the ultimate analyses of the coal samples. The oxygen content of the coal in the basin area increases toward the southeast (fig. 8). Figure 7 shows that the fixed carbon and ash content increase toward the northwest, and that the moisture and volatile matter are similar throughout the basin. The carbon, hydrogen, nitrogen, and sulfur contents (fig. 8), show no directional trends.

Environmental deposition

The Frontier Formation consists of 600-1,000 ft of marine and nonmarine sandstone, siltstone, shale, bentonite, volcanic tuff, coal, underclay, and limestone. The coal-bearing part of the formation was deposited in a broad coastal swamp environment that developed on a prograding delta system. The Frontier Formation crops out as three to five resistant sandstone ridges and two to four less resistant shale troughs. In places, the coal is multiple bedded and is as much as 42 in. thick in the Wilderness bed in the Blue Holes quadrangle. The Wilderness coal bed and adjacent strata of the Frontier Formation have been thrust over rocks of Eocene age and are truncated by the fault.

The Mesaverde Formation consists of a thick sequence of sandstone, siltstone, shale, bentonite, coal, underclay, and thin silty dolomitic limestone units, and is 1,500-2,200 ft thick. The coal beds are mostly of subbituminous rank and many contain numerous tonsteins recording episodes of volcanic ash-fall. Coal beds as much as 120 in. thick in the Mesaverde

Formation have been identified in oil and gas wells at depths of more than 14,500 ft. Coal-bearing rocks of the Mesaverde Formation have also been identified in recent oil and gas wells in an elongate, down-folded, sub-basin of the Wind River Basin along its southwestern edge (fig. 2).

The Meeteetse Formation is conformable on the Mesaverde Formation and consists of sandstone, siltstone, shale, bentonite, coal, and underclay. Generally, lithologic units are thin, lensatic, and discontinuous. Exceptions are several widespread coal beds. Subsurface data indicate that the Meeteetse Formation is as much as 4,600 ft thick in the central part of the Wind River Basin, and contains more than 100 coal beds.

Peat accumulation in early Mesaverde time was widespread and of long duration. Initial coal development was in coastal swamps formed above thick sandstone bodies related to a distributary channel coastal barrier bar and prograding delta system, similar to the depositional environment of the Pocahontas Formation in the Appalachian Basin (Englund and others, 1984).

During the deposition of the Meeteetse Formation, a different environment influenced peat accumulation. A more restricted intermontane basin began developing as a positive or uplifted area formed at or north of the modern location of the Owl Creek Mountains. The central part of the basin subsided and many peat deposits of variable thickness accumulated. Wide variations in coal-bed thickness and intervals between beds suggest an unstable migrating swamp perimeter resulting from sediment derived from several emerging highland areas similar to the Paleocene coal-bearing sequences in the Powder River Basin (Kent, 1984). Volcanic eruptions were common and numerous bentonitic sandstone and shale beds, beds of bentonite, and tonsteins in coal beds record these events.

Analytical data for coal beds in the Mesaverde and Meeteetse Formations suggest that differences in the depositional environment have affected the quality of the coal. The most obvious difference is the high ash content of coal beds in the Meeteetse Formation which is almost twice as high as that in the Mesaverde Formation. Silica content of ash in coals of the Meeteetse Formation is higher than coals of the Mesaverde Formation and may be due to the increased amount of volcanic material introduced in reworked terriginous sediments. Coals in the Mesaverde Formation contains significantly more sulfur than those in the Meeteetse Formation probably because of the influence of marine and brackish-water sedimentary succession (Ferm and others, 1976; Horne and others, 1978).

Summary

Overall, the quality of coals in the Wind River Basin is similar to that of other sampled western subbituminous coals. Consequently, the marketability of these coals should be competitive with other western coals.

- Btu/lb values range from 7,256 to 11,472 on an as-received basis. This range is comparable with other sampled subbituminous coals in the Rocky Mountains. The geometric mean values (9,446 versus 9,410 Btu/lb) also are similar. The heat-of-combustion determines the price; mineability and price revenues obtained from marketing of the coal determines whether a coal can be mined at a profit.

- Ash-content ranges from 1.8 to 25.9 percent. The geometric mean value is 10.1 percent, which suggests that the ash content of these coal beds is within that normally mined and used in various coal-combustion processes.

- The total sulfur content ranges from 0.3 to 3 percent, spanning the low- to high-sulfur range. However, the geometric mean value of 0.9 percent suggests that the coals are mostly within the low-sulfur category which is characteristic of most sampled western U.S. coals.

- Pyritic sulfur ranges in value from 0.02 to 2.49 percent. This suggest that such a range in the sulfur content can be attributed to pyritic sulfur in the coal beds. Pyritic sulfur and total sulfur content of more than one percent reduce the marketability of the coal and can affect the clean-air standards of the area where used. Most coals having a high pyritic sulfur content can be cleaned or can be used in other processes.

- The mean values for ash-fusion temperatures of coal samples from the Wind River Basin are about 100°F higher than those of other sampled Rocky Mountain subbituminous coal beds. These temperatures affect the boiler fouling properties of the ash. Higher ash fusion temperatures reduce boiler fouling tendencies.

- The concentration of the alkali oxides (Na_2O, K_2O, Fe_2O_3, and CaO) in coal determines the ash-fusion temperature and ultimately the corrosion, clogging, and efficiency of combustion furnaces. A low concentration of these oxides in the Wind River Basin coals produces the high ash-fusion temperatures previously noted.

- Chemical elements of environmental concern such as arsenic, selenium, antimony, mercury, lead, and so on, are found in the sampled Wind River Basin coal beds in approximately the same concentration as they are found in the other sampled western subbituminous coals. Use of these coals in combustion processes would produce environmental effects that are similar to those of other western U.S. coals.

References

American Society for Testing aand Materials, 1981, Annual Book of ASTM Standards; p. 26, Gaseous Fuels; Coal and Coke; Atmosphere Analysis: Philadelphia, Pennsylvania, p. 212-399.

Berryhill, H.L., Jr., Brown, D.M., Brown, Andrew, and Taylor, D.A., 1950, Coal resources of Wyoming: U.S. Geological Survey Circular 81, 78 p.

Comstock, T.B., in Jones, W.A., 1874, Report upon the reconnaissance of northwestern Wyoming in 1873: U.S. 43d Congress, 1st Session, H.R. Executive Doc. 285, 210 p.

Darton, N.H., 1906, Geology of the Owl Creek Mountains: U.S. 59th Congress, 1st Session, S.N. Executive Doc. 219, 48 p.

Eldridge, G.H., 1894, A geological reconnaissance in northwest Wyoming, with special reference to its economic resources: U.S. Geological Survey Bulletin 119, 72 p.

Englund, K.J., Windolph, J.F., Jr., and Thomas, R.E., 1984, Deposition of low-sulfur coal in the Lower Pennsylvanian Pocahontas Formation, Virginia and West Virginia: Geological Society of America: Abstracts with Programs, V. 16, No. 6, p. 502.

Ferm, J.C., Horne, J.C., and Melton, R.A., 1976, Depositional models applied to coal exploration and development: American Institute Mining Engineers Annual Meeting, Las Vegas, Nev., February 1976, 12 p.

Glass, G.B., and Roberts, J.T., 1978, Update on the Wind River Coal Basin, in Boyd, R.G., ed., Resources of the Wind River Basin: Wyoming Geological Association Guidebook, No. 30, p. 363-377.

Hayden, F.V., 1869, Geological report of the exploration of the Yellowstone and Missouri Rivers: U.S. 40th Congress, 2d Session, Sen. Executive Doc. 77, 174 p.

Horne, J.C., Howell, D.J., Baganz, B.P., and Ferm, J.C., 1978, Splay deposits as an economic factor in coal mining, in Hodgson, H.E., ed., Proceedings of the second symposium on the geology of Rocky Mountain coal--1977: Colorado Geological Survey Resources, Ser. 4, p. 89-99.

Keefer, W.R., 1961, The Meeteetse, Lance, and Fort Union Formations, southern Wind River Basin, Wyoming: in Symposium on Late Cretaceous rocks, Wyoming and adjacent areas, Wyoming Geological Association, 16th Annual Field Conference, 1961: Casper, Wyoming, Petroleum Information, p. 180-186.

---- 1970, Structural geology of the Wind River Basin, Wyoming: U.S. Geological Survey Professional Paper 495-D, 35 p.

---- 1972, Frontier, Cody, and Mesaverde Formations in the Wind River and southern Bighorn Basins, Wyoming: U.S. Geological Survey Professional Paper 495-E, p. E1-E23.

Kent, B.H., 1984, Evolution of thick coal deposits in the Powder River Basin, northeastern Wyoming: Geological Society of America, Abstracts with Programs, V. 16, No. 6, 1p. 558.

Knight, W.C., 1895, Coals and coal measures of Wyoming: in U.S. Geological Survey 16th Annual Report, pp. IV: 8 p.

Seeland, D.A., and Branch, E.F., 1975, Status of mineral resource information for the Wind River Indian Reservation, Wyoming: Administrative Report BIA-8, prepared for the U.S. Bureau of Indian Affairs by the U.S. Geological Survey and the U.S. Bureau of Mines, 66 p.

Swanson, V.E., and Huffman, Claude, Jr., 1976, Guidelines for sample collecting and analytical methods used in the U.S. Geological Survey for determining chemical composition of coal: U.S. Geological Survey Circular 735, 11 p.

Swanson, V.E., Medlin, J.H., Hatch, J.R., Coleman, S.L., Wood, G.H., Jr., Woodruff, S.D., and Hildebrand, R.T., 1976, Collection, chemical analysis and evaluation of coal samples in 1975: U.S. Geological Survey Open-File Report 76-468, 503 p.

Thompson, R.M., and White, V.L., 1952, the coal deposits of the Alkali Butte, the Big Sand Draw, and the Beaver Creek fields, Fremont County, Wyoming: U.S. Geological Survey Circular 152, 24 p.

Troyer, M.L., and Keefer, W.R., 1955, Geology of the Shotgun Butte area, Fremont County, Wyoming: U.S. Geological Survey Oil and Gas Investigations Map OM-172.

Windolph, J.F., Jr., Hickling, N.L., and Warlow, R.C., 1980, Report of 1978-1979 field investigations of coal resources in the Wind River Indian Reservation, Fremont County, Wyoming; U.S. Geological Survey Open-File Report OF-80-674, 14 p., 1 plate.

Woodruff, E.G., 1907, the Lander Coal Field, Wyoming: U.S. Geological Survey Bulletin 316, p. 242-243.

Woodruff, E.G., and Winchester, D.E., 1912, Coal fields of the Wind River region, Fremont and Natrona Counties, Wyoming: U.S. Geological Survey Bulletin 471, p. 516-564.

Zobovic, Peter, Oman, C.L., Bragg, L.J., Coleman, S.L., Rega N.H., Lemaster, M.E., Rose, H.J., Golightly, D.W., and Puskas, John, 1980, Chemical analysis of 659 coal samples from the eastern United States: U.S. Geological Survey Open-File Report 80-2003, 517.