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Geological Survey

Coal Quality of a Core from the Wyodak-Anderson Coal Bed, Southeastern Powder River Basin, Wyoming:

A Preliminary Study

By

Sharon S. Crowley, Ronald W. Stanton, and
Peter D. Warwick

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This report is preliminary and has not been
edited or reviewed for conformity with U.S.
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Abstract

A 22-m (73 ft) length of core from the Wyodak-Anderson coal bed (Paleocene) in the southeastern Powder River Basin was divided into 29 samples for petrographic and chemical analysis. Cluster analysis permitted the identification of samples with similar maceral and chemical compositions. Petrographic data consisted of 24 maceral varieties in vitrinite, liptinite, and inertinite groups; chemical data consisted of 26 elements, volatile matter, fixed carbon, and forms of sulfur. Preliminary results indicated that coal sampled directly above and below a 7.1-cm-thick (2.8 in) shale parting is significantly different from coal sampled in other parts of the core. Coal sampled next to the parting contained abundant liptinites (primarily bituminite and liptodetrinite), low percentages of inertinites, and high levels of sulfur (organic and pyritic) compared to samples from other areas in the coal bed. On the basis of these results, we infer that the coal sampled directly above and below the shale parting formed from peat deposited in a subaquatic, anaerobic environment.

Acknowledgments

We would like to express our appreciation to the Thunder Basin Coal Company for their cooperation in the collection of core samples in the southeastern Powder River Basin, Wyoming. We are also grateful to the late Wayne R. Sigleo and to Edward A. Johnson of the U.S. Geological Survey, who laid the groundwork for this project and made the entire study possible.

Introduction

A 22 m (73 ft) length of core from the Wyodak-Anderson coal bed (Paleocene) in the southeastern Powder River Basin, Wyoming (fig. 1) was divided into 29 samples for petrographic and chemical analyses. Coal samples were examined microscopically to determine maceral composition, and all samples were analyzed for concentrations of 51 elements, forms of sulfur, fixed carbon, and volatile matter. Cluster analysis provided a means to classify the samples by their maceral and chemical composition.

Although numerous studies have been made of the Wyodak-Anderson and other coal beds in many parts of the Powder River Basin, studies are somewhat limited in the southeastern section of the Powder River Basin. Budai and Cummings (1987) reported on the Canyon and Anderson coal beds in the Antelope Coal Field, located about 20 km (13 mi) southwest of the study area. Results of their study indicated that the coal-bearing sediments were deposited in paludal and tributary subsystems, and that deposition of the Canyon and Anderson coal beds may have occurred when a river system underwent anastomosis (Budai and Cummings, 1987). Pierce and Johnson (1988) conducted a facies analysis of the rock sequence below the Upper Wyodak coal bed, at three locations along the

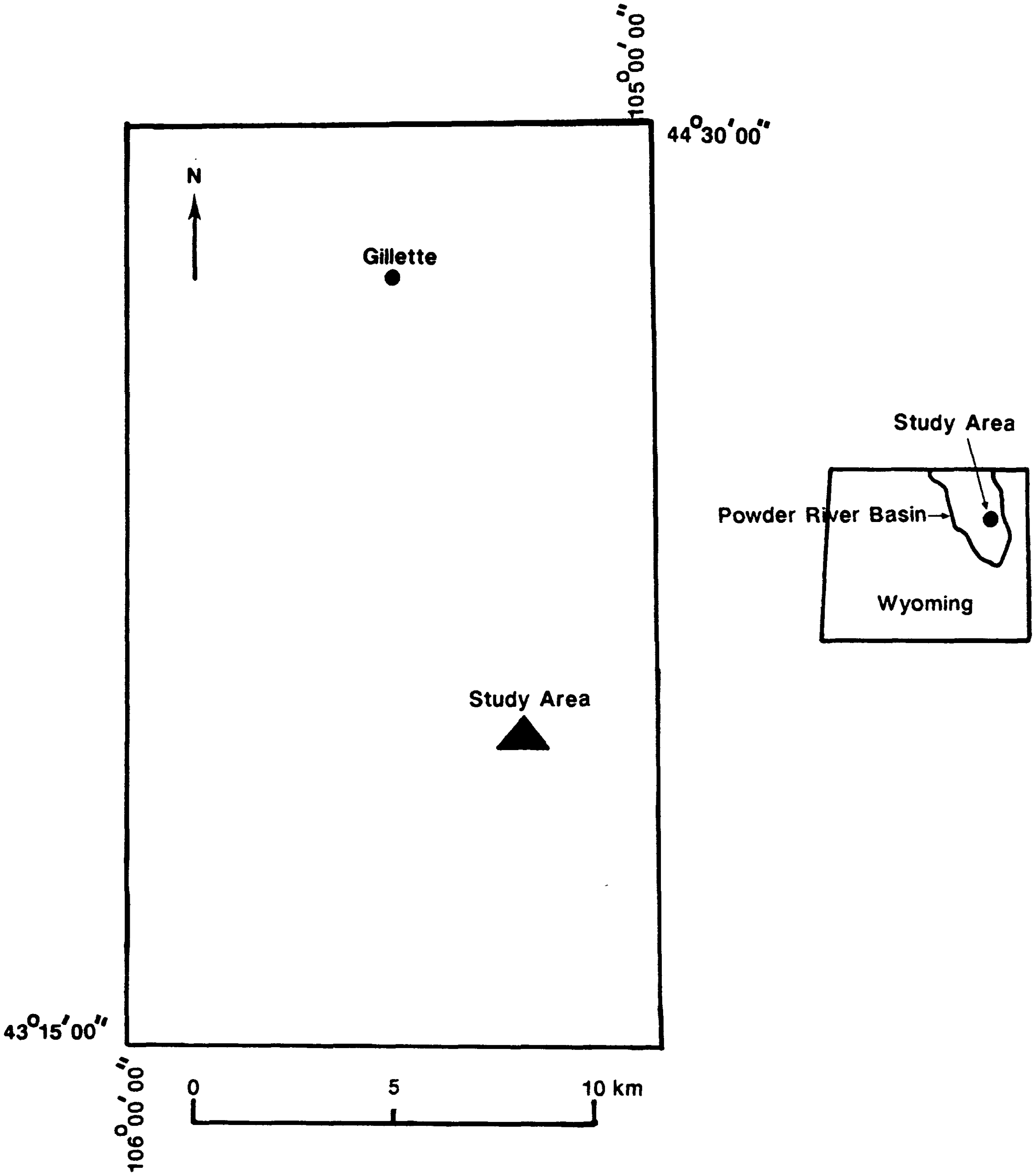


Figure 1. Location of the study area.

southeastern margin of the Powder River Basin. Their preliminary results indicated channel, overbank sand, floodplain and swamp deposits in an alluvial plain environment (Pierce and Johnson, 1988). Neither of these studies, however, included information on the petrographic or chemical aspects of the coal associated with the rock units.

Reports on the Wyodak-Anderson coal bed in other parts of the Powder River Basin interpreted the Wyodak-Anderson coal bed to be laterally extensive (Denson and Keefer, 1974; Glass, 1980; and Kent, 1986). Kent (1986) suggested that the Wyodak bed in the Gillette area is split into several coal beds to the west. In contrast, other work based on closely spaced drill core data in the Gillette area, showed that the Wyodak-Anderson coal bed consists of vertically offset, laterally discontinuous bodies of coal that developed from peat deposited in an alluvial setting (Warwick and Stanton 1986, 1988a, 1988b; Stanton and others, 1988, in press; Flores and others, 1988). These 3 by 4 km (2.0 by 2.5 mi) coal bodies or pods probably were derived from peat that developed in swamps between anastomosed channels. These fluvial depositional models contrast with those of Ayers and Kaiser (1984), who suggested that thick coals (up to 60 m or 200 ft) in the Powder River Basin formed between deltaic lobes that were deposited in a large lake.

Methods

A core obtained from the Thunder Basin Coal Company in the Powder River Basin study area was cut longitudinally in the field using a masonry saw with a carbide blade. One-half of the core was obtained by the U.S. Geological Survey for petrographic and analytical analyses. The core was divided into 29 samples (27 coal samples and 2 rock samples) on the basis of megascopic identifiable lithologies and x-radiography (see vertical section, fig. 2). Samples were labeled sequentially from the top to bottom of the core (558.01 to 558.35), except where core was not recovered (i.e., no record is available for samples 558.03 to 558.08). Samples 558.12 and 558.35 are rock samples. Splits were then prepared from each sample and analyzed for maceral and chemical composition.

The petrographic composition of 27 coal samples was determined by using reflected light microscopy. Polished pellets were prepared following the American Society for Testing Materials guidelines (1987a) and macerals were point-counted in two stages: 1) under blue-light fluorescence for liptinite macerals, and 2) under white light (using etched polished surfaces) for huminite and inertinite varieties. A total of 2000 points were counted for each sample, and count data for each pellet were compared

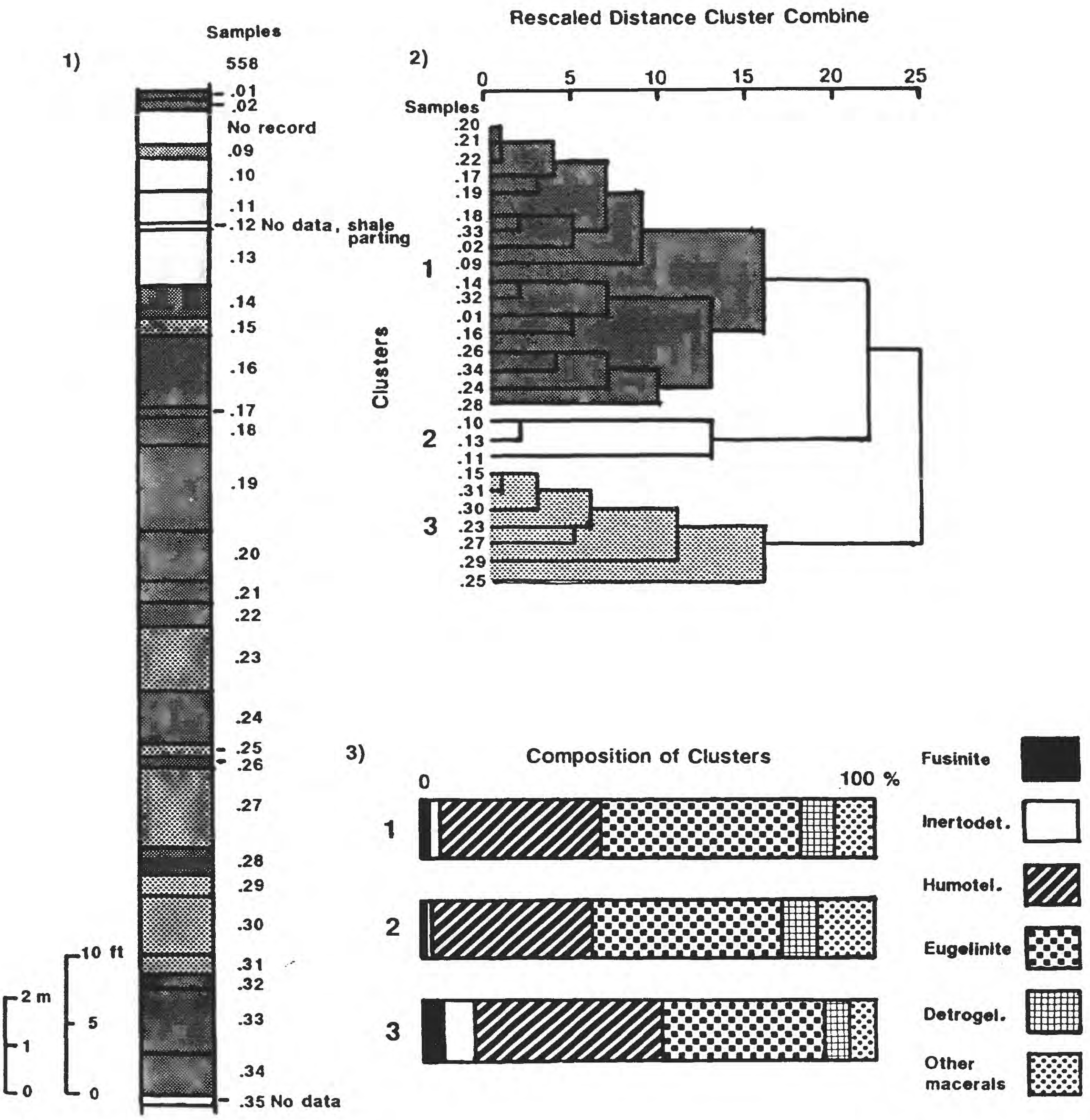


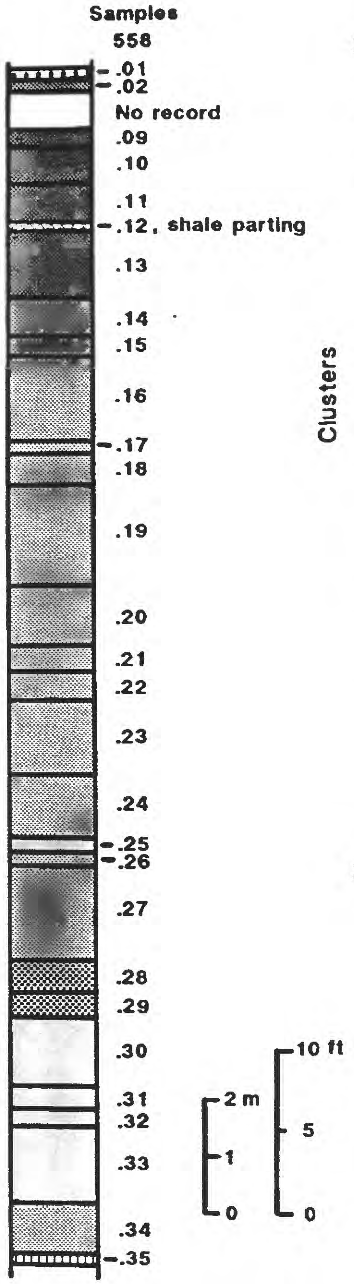
Figure 2. Cluster analysis of the maceral data: 1) vertical section of the Powder River Basin core; 2) dendrogram produced by cluster analysis; and 3) maceral composition of each cluster.

according to ASTM guidelines for analytical precision (American Society for Testing Materials, 1987b). Petrographic data are presented in table 1 (appendix A). The maceral composition of two samples (558.12 and 558.35) was not determined because their high ash content precluded precise maceral identification.

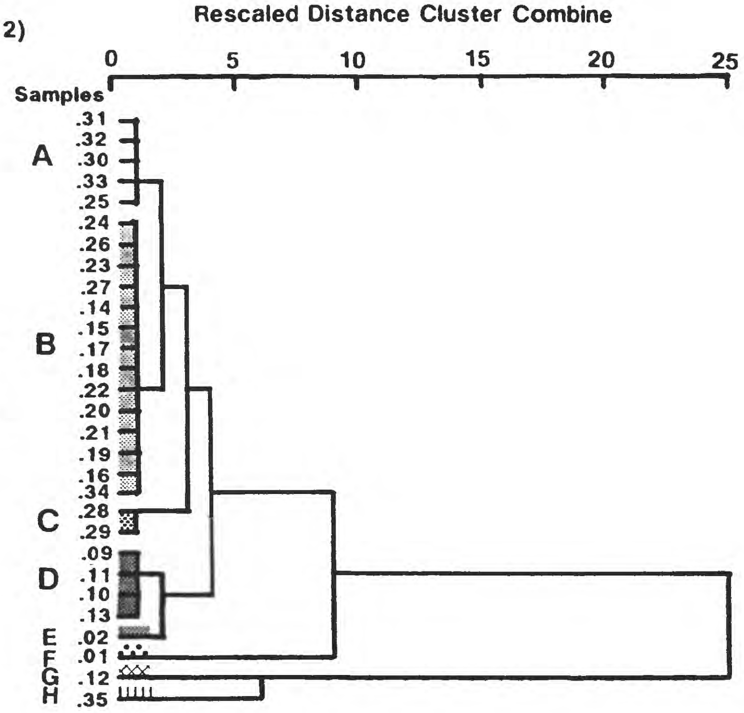
All 29 samples were analyzed for proximate and sulfur data (table 2a; appendix B). Chemical data for 51 elements were obtained from x-ray fluorescence, atomic absorption (wet chemical), and optical emission spectrographic analyses made at the U.S. Geological Survey (table 2b, 2c, and 2d; appendix B). Precision levels for these methods are summarized in the U.S. Geological Survey Bulletin 1823 (Golightly and Simon, in press). All chemical data used in this study were recalculated to a whole coal basis, as necessary, before inclusion in cluster analysis.

Q-mode cluster analysis, which groups samples that have similar compositions, was applied separately to the petrographic and chemical data to determine the vertical variation of the macerals and chemical elements in the core. Core samples were coded according to the cluster group and plotted on a vertical section of the core (figs. 2 and 3). Methods used in the cluster analyses were the Complete Linkage Method and the Squared Euclidean Measure

1)



2)



3) Variables used in cluster analysis:

Volatile matter, fixed carbon, sulfate, pyritic sulfur, organic sulfur, SO_3, TiO_2, MgO, Na_2O, Li, Cu, Zn, Cd, Pb, Mn, Ga, Mo, Nb, Ni, Sr, V, Zr, Y, SiO_2, Al_2O_3, Fe_2O_3, CaO, K_2O, Ag, B, and Ba.

Figure 3. Cluster analysis of the chemical data: 1) vertical section of the Powder River Basin core; 2) dendrogram produced by cluster analysis; and 3) variables used in cluster analysis.

(Norusis/SPSS Inc., 1988).

The cluster analysis by petrographic composition used 24 variables (maceral varieties, table 1, appendix A). The cluster analysis by chemical composition used 31 variables. Chemical variables include volatile matter, fixed carbon, sulfur forms, and 26 elements on a whole-coal dry basis (fig. 3). Qualified chemical data (values less than a specified limit) were excluded from the cluster analysis.

Results

Maceral Analysis

Three major sample clusters were defined by cluster analysis of the maceral data (fig. 2). Mean values for each of the sample clusters are listed in table 3. Cluster 3 samples are located primarily in the lower half of the coal bed; cluster 2 samples are located next to the shale parting (558.12); and cluster 1 samples occur throughout the coal bed.

Cluster 3 samples contain more fusinite and inertodetrinite (a total of 12 percent) than cluster 1 or 2 samples. Cluster 3 also contains slightly more humotelinite (42 percent) and less detrogelinite (6 percent) than the

Table 3. Mean values for Q-mode clusters of maceral data (expressed as point counts per 1000).

	Cluster 1	Cluster 2	Cluster 3
Vitrinites			
Humotelinite	358	357	418
Eucorpocollinite	10	22	10
Poricorpocollinite	15	17	9
Eugelinite	437	412	348
Porigelinite	1	2	0
Detrogelinite	75	77	55
Eucorpocol. in gel.	4	4	3
Poricorpocoll. in gel.	2	4	1
Porigelinite in humotel.	5	2	6
Liptinites			
Sporinite	28	17	10
Cutinite	0	2	0
Attrital resinite	2	2	1
Resinite	1	1	1
Exsudatinite	1	0	1
Fluorinite	2	2	2
Bituminite	4	31	4
Alginite	0	0	0
Liptodetrinite	12	19	5
Suberinite	0	1	0
Inertinites			
Fusinite	19	13	49
Semifusinite	2	3	7
Macrinite	1	2	2
Inertodetrinite	20	10	67
Sclerotinite	2	0	1

other 2 clusters. Cluster 2 samples, on the other hand, contain less fusinite and inertodetrinite (2 percent) than the other clusters. Cluster 2 samples also contain abundant liptinites (8 percent), with relatively large percentages of bituminite (3 percent) and liptodetrinite (2 percent). Cluster 1 samples are comprised of intermediate levels of total liptinites and inertinites. However, these samples contain more sporinite (3 percent) than the other clusters.

Bar charts depicting the percentage of selected maceral varieties in each cluster show how the clusters differ in average maceral composition (fig. 2). The distribution of selected maceral varieties in the Powder River Basin core is shown in Figure 4.

Chemical Analysis

Cluster analysis of the chemical data produced 8 sample groups (fig. 3). Mean values for each of the sample clusters are listed in Table 4. Because four of the cluster groups (E, F, G, and H) consist of only one sample and have ash yields greater than or equal to 10 percent, the following discussion pertains primarily to clusters A through D.

Cluster D is composed of 4 samples located above and below the shale parting (sample 558.12, fig. 3) and near the

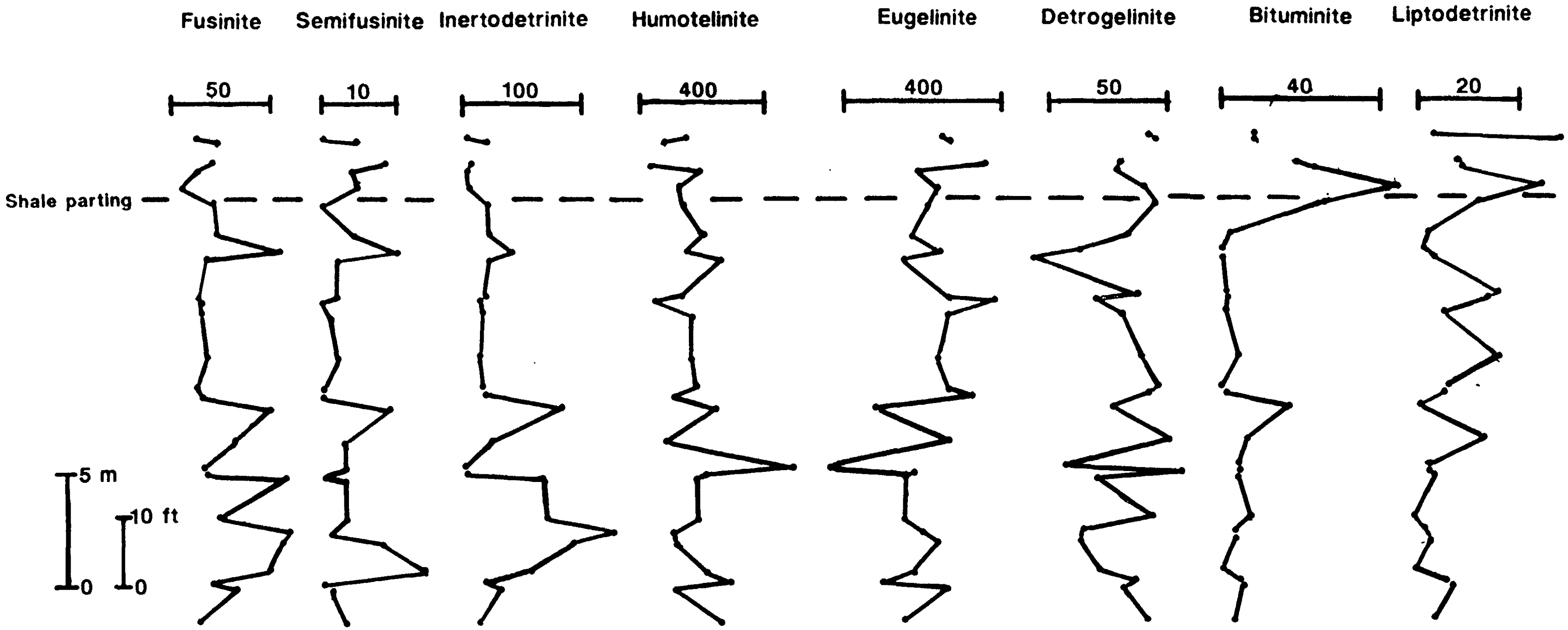


Figure 4. Distribution of selected maceral varieties in the Powder River Basin core. (Units of measure are expressed as point counts per 1000.)

Table 4. Mean values for Q-mode chemical clusters. (Volmat=volatile matter, Fixedc=fixed carbon, Sulfpyr=pyritic sulfur, Sulforg=organic sulfur).

	A	B	C	D	E	F	G	H
Ash (%)	4.1	5.9	8.8	8.0	10.	14.	52.	73.
Volmat (%)	43.7	45.1	40.8	45.6	46.8	42.8	26.8	18.3
Fixedc (%)	52.1	48.7	49.8	45.9	43.9	42.8	21.1	8.1
Sulfate(%)	.02	.04	.03	.07	.23	.63	.07	.08
Sulfpyr(%)	.09	.10	.05	.23	.21	.60	.12	.10
Sulforg(%)	.14	.28	.28	.86	.86	1.0	.40	.12
SO_3 (%)	.83	1.2	1.0	2.3	3.0	2.4	1.5	.83
TiO_2 (%)	.02	.06	.13	.07	.06	.09	.81	.72
MgO (%)	.23	.29	.27	.27	.33	.26	.38	.58
Na_2O (%)	.02	.02	.02	.02	.03	.03	.06	.10
SiO_2 (%)	.73	1.5	2.9	2.3	3.1	4.9	33.	45.
Al_2O_3 (%)	.58	.92	2.0	1.4	1.5	2.7	12.	20.
Fe_2O_3 (%)	.21	.19	.20	.40	.75	1.9	.39	1.2
CaO (%)	1.2	1.5	1.5	1.4	1.6	1.2	1.1	.66
K_2O (%)	.01	.02	.04	.03	.04	.11	.37	1.1
Ag (ppm)	.02	.03	.06	.05	.02	.07	.28	.46
B (ppm)	24.	49.	54.	66.	47.	60.	57.	69.
Ba (ppm)	310.	280.	810.	350.	190.	110.	370.	800.
Cd (ppm)	.02	.02	.03	.04	.06	.11	.16	.37
Cu (ppm)	4.0	9.7	14.	14.	9.7	14.	88.	73.
Ga (ppm)	.96	2.3	5.3	3.0	2.6	12.	20.	34.
Li (ppm)	.44	2.4	2.3	2.1	1.7	3.8	16.	28.
Mn (ppm)	6.3	10.	12.	13.	17.	14.	24.	17.
Mo (ppm)	.95	.73	1.2	1.9	2.3	4.8	5.7	8.8
Nb (ppm)	1.2	1.9	6.9	1.6	1.7	2.3	20.	29.
Ni (ppm)	5.2	3.7	3.6	8.0	12.	31.	20.	34.
Pb (ppm)	2.4	3.8	5.4	4.6	5.5	7.5	23.	33.
Sr (ppm)	240.	290.	600.	350.	250.	170.	160.	240.
V (ppm)	7.5	12.	25.	18.	13.	45.	110.	230.
Y (ppm)	2.7	2.9	4.5	7.3	21.	23.	13.	21.
Zn (ppm)	3.5	3.9	4.6	7.3	9.3	26.	21.	59.
Zr (ppm)	20.	31.	70.	33.	32.	40.	130.	250.

top of the coal bed. These samples have high ash yields (8.0 percent) and high levels of sulfur (pyritic sulfur=0.23 percent, organic sulfur=0.86 percent) compared to clusters A, B, and C. In addition, cluster D has relatively high levels of the following elements: Zn (7.3 ppm), Mn (13 ppm), Mo (1.9 ppm), Ni (8.0 ppm), Y (7.3 ppm), B (66 ppm), and Fe_2O_3 (0.4 percent). Cluster C samples also have relatively high ash yields (8.8 percent). In addition, the following elements are highly concentrated in cluster C samples compared to cluster A, B, and D: Nb (6.9 ppm), Sr (600 ppm), Zr (70 ppm), V (25 ppm), and Ba (810 ppm).

Clusters A and B contain samples with the lowest ash values (cluster 1=4.1 percent, cluster 2=5.9 percent) of all 8 clusters. They also contain the lowest concentrations of nearly all of the elements studied. As the dendrogram indicates (fig. 3), clusters A and B are very similar.

The distribution of selected variables (ash yield and 9 elements) in the Powder River Basin core is shown in Figures 5 and 6.

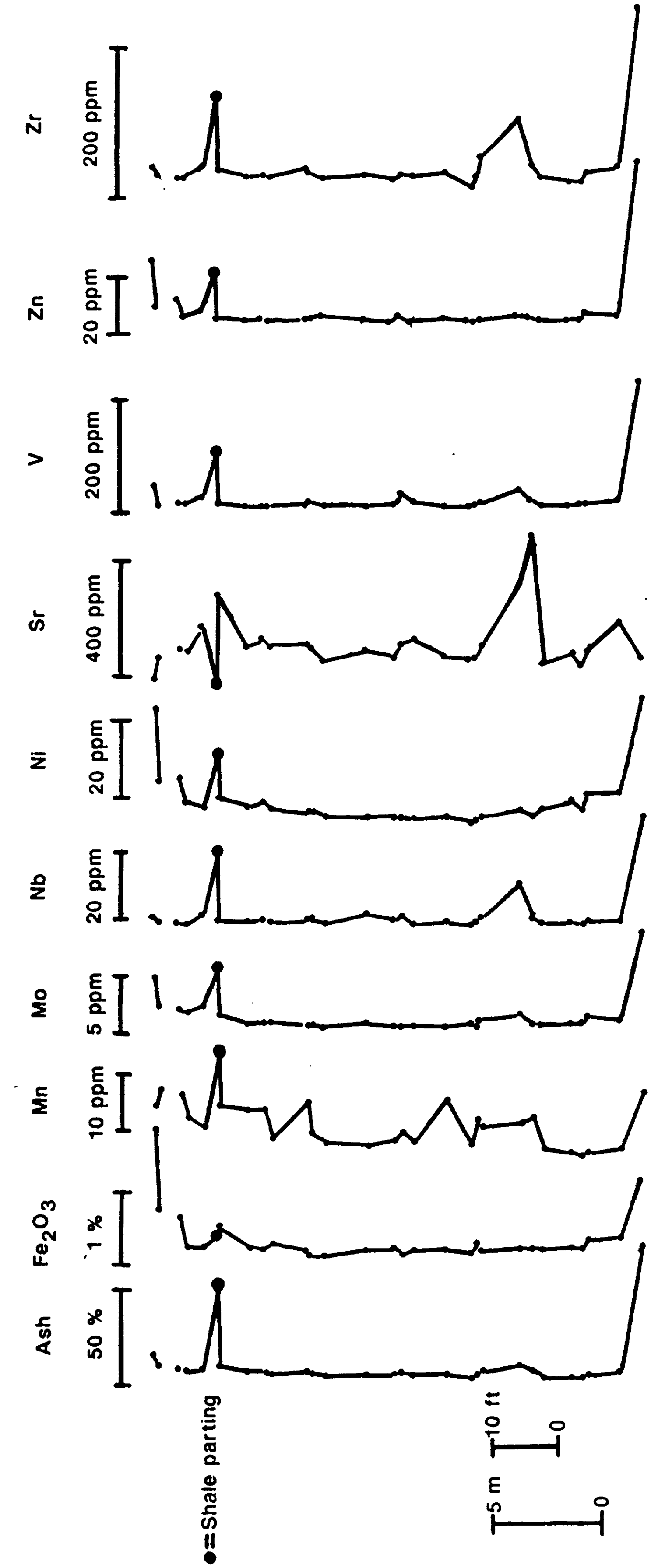


Figure 5. Distribution of ash and selected elements (on a whole-sample basis) in the Powder River Basin core.

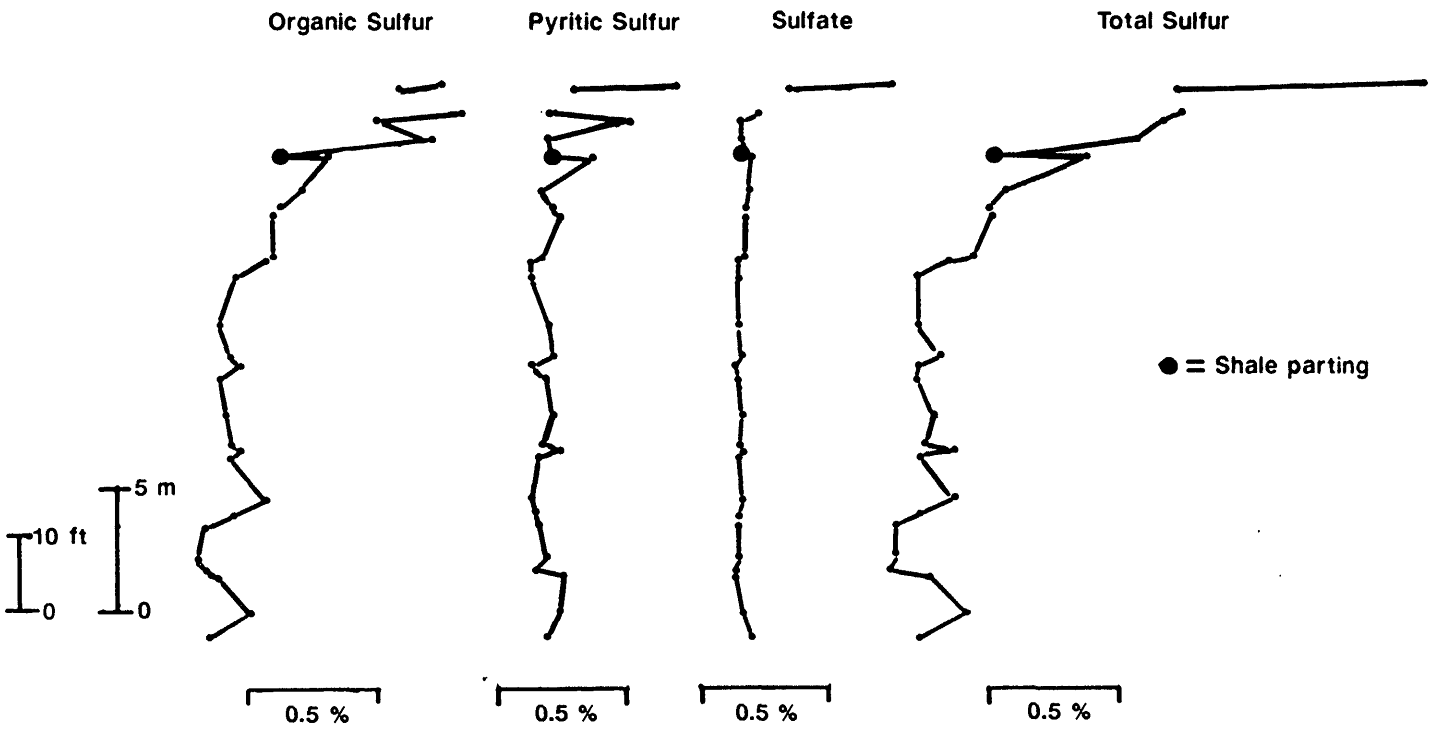


Figure 6. Distribution of the forms of sulfur and total sulfur in the Powder River Basin core.

Discussion

The preliminary results of this study indicate that unique clusters of samples are located next to the shale parting near the top of the coal bed (cluster 2, fig. 2; cluster D, fig. 3). These samples have relatively high ash yields and contain abundant bituminite and liptodetrinite. They are also highly concentrated in pyritic sulfur, organic sulfur, and elements associated with sulfides (Zn and Fe_2O_3).

The peat that formed the coal next to the shale parting may have developed in a subaquatic, anaerobic environment. Stach and others (1982) reported that sapropelic coals and other subaquatic, liptinite-rich coals contain abundant bituminite and liptodetrinite. Sapropelic peat develops as subaquatic muds, under conditions that are more anaerobic than those for humic peat (Stach and others, 1982). A subaquatic or poorly drained peat swamp environment would also explain the relatively low levels of fusinite found in the coal samples near the parting, because inertinite macerals form through processes such as fire or desiccation (Stach and others, 1982).

The occurrence of highly concentrated pyritic sulfur in cluster D samples lends further support to the development of peat near the shale parting in anaerobic, subaqueous muds.

Because sulfate-reducing bacteria are anaerobes, a completely reducing environment must be maintained for the initial formation of sulfides (Gottschalk, 1979). Previous studies indicated that anoxic conditions generally exist in the majority of subaqueous sediments. Berner (1984) suggested that organic matter acts as an oxygen-consuming barrier in subaqueous sediments. Clymo (1983) reported that the rate of oxygen diffusion would be insufficient to support microbial activity in peat a few centimeters (1-2 inches) below the water table during the late spring, which would cause the peat to become anaerobic. Sources of iron for pyrite formation probably included highly reactive ferric oxide coatings on clays and silts or somewhat less reactive clay minerals and unweathered primary minerals (Berner, 1984). These were probably introduced to the peat by the fluvial processes that formed the shale parting or roof rock. The sulfate necessary for pyrite formation could have been introduced as sulfate ions in ground and surface water (Stach and others, 1982), or as a product of organic decay (Altschuler and others, 1983).

In contrast to samples of maceral cluster 2, samples of maceral cluster 3 (samples located in the lower part of the core) contain relatively high levels of fusinite and inertodetrinite (fig. 2). The presence of these inertinite macerals suggest that fire or desiccation processes were more dominant than in cluster 2 samples, and that the peat probably was fairly well drained.

The chemical cluster C consists of 2 samples in the lower part of the core (fig. 3) that have a relatively high ash yield and high levels of Zr and Nb. Previous work indicates that zircons may contain Nb in addition to Zr (Wedepohl, 1978 and Finkelman, 1980). The data from our study suggest that zircons were introduced to the peat swamp from an outside source by fluvial or volcanic activity. The results of this study are preliminary in nature. Further work is in progress to examine the palynological and mineralogical composition of the Powder River Basin core.

Summary

Cluster analysis of maceral and chemical data for the 22-m (73 ft) length of core from the Wyodak-Anderson coal bed indicates that coal located next to a 7.1-cm-thick (2.8 in) shale parting contain more liptinites (primarily bituminite and liptodetrinite), fewer inertinites, and more sulfur (organic and pyritic) than coal from other parts of the core. We conclude that coal next to the parting formed in a subaquatic, anaerobic environment.

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Appendix A - Maceral Data

Table 1. Maceral Data (Units are point counts, with a total of 1000 counts per sample, on a dry mineral-free basis. SP=sporinite, CT=cutinite, RD=resinite, RS=resinite in telinite, EX=exsudatinite, FL=fluorinite, BT=bituminite, A=alginite, LP=liptodetrinite, SB=suberinite, HM=humotelinite, EC=eucorpocollinite, PC=poricorpocollinite, EG=eugelinite, PG=porigelinite, DG=detrogelinite, E2=eucorpo. in gelinite, P2=poricorpo. in gelinite, PG2=porigelinite in telinite, FS=fusinite, SF=semifusinite, MC=macrinite, IT=inertodetrinite, SC=sclerotinite.)

	SP	CT	RD	RS	EX	FL	BT	A	LP	SB	HM	EC	PC	EG	PG	DG	E2	P2	PG2	FS	SF	MC	IT	SC
BT558.01	29	0	3	0	1	3	8	0	7	0	350	10	33	447	0	81	4	5	0	12	0	3	4	0
.02	56	0	1	0	0	2	8	0	33	0	277	11	8	469	0	83	4	1	0	23	5	0	20	1
.09	38	2	4	3	1	6	19	0	12	0	235	4	7	554	4	69	4	2	0	20	8	0	6	2
.10	22	0	2	1	0	2	23	0	13	1	401	22	24	387	1	68	6	4	4	13	4	0	4	0
.11	15	5	1	2	0	3	44	0	29	0	329	20	9	437	3	79	2	4	0	5	5	5	5	0
.13	14	2	4	0	1	0	25	0	16	1	343	24	18	412	1	84	5	4	1	22	0	3	22	0
.14	22	0	0	0	0	0	2	0	6	0	409	31	18	373	0	72	5	2	8	23	4	3	22	1
.15	9	0	0	0	0	0	0	0	5	0	352	10	10	441	0	52	5	1	4	56	10	2	41	3
.16	19	0	2	0	0	0	0	0	7	0	469	11	54	350	0	32	4	3	6	18	2	0	23	1
.17	32	0	3	0	0	0	1	0	20	0	330	9	11	461	3	76	10	3	5	13	2	2	18	3
.18	33	0	3	2	0	2	1	0	18	0	245	4	6	582	0	59	5	0	8	14	0	1	15	4
.19	17	0	0	0	0	3	1	0	9	0	369	9	13	461	2	70	8	1	3	16	1	3	16	0
.20	18	1	2	0	0	1	4	0	20	0	367	8	21	437	0	78	3	2	6	18	2	0	13	0
.21	11	0	1	0	0	0	0	0	10	0	381	4	7	465	1	84	5	2	1	13	0	0	16	0
.22	12	2	4	2	0	2	1	0	9	0	308	5	4	524	1	79	4	2	4	16	0	1	20	1
.23	7	1	1	1	0	0	17	1	4	0	451	13	14	275	0	65	3	2	1	50	9	3	84	1
.24	3	0	0	2	0	0	6	1	17	0	278	12	11	472	0	89	2	3	9	32	3	4	25	5
.25	9	0	0	0	1	0	4	0	6	0	714	8	15	161	0	45	2	0	15	17	3	0	2	0
.26	41	0	1	0	2	4	4	1	6	0	414	10	11	374	3	94	2	0	9	18	0	1	3	3
.27	22	0	3	1	0	3	4	0	7	0	386	11	5	355	0	59	2	0	12	58	3	4	67	0
.28	14	2	5	5	0	5	7	1	3	0	386	12	21	351	0	83	1	1	8	24	3	0	69	1
.29	15	1	0	4	5	0	3	0	5	0	300	17	4	396	0	52	0	1	6	60	1	0	130	1
.30	6	0	2	0	0	7	3	0	6	0	307	6	11	435	0	52	3	2	2	56	8	2	92	1
.31	5	0	1	3	0	3	0	0	3	0	415	9	6	371	0	60	5	1	0	49	14	1	52	2
.32	35	0	1	0	0	2	4	0	9	0	496	15	15	292	2	74	5	1	9	19	0	1	18	2
.33	36	0	2	2	3	4	5	0	11	0	304	9	9	462	0	69	7	1	6	33	1	2	32	3
.34	26	0	5	1	2	2	3	1	7	0	465	6	9	348	0	81	1	2	11	13	3	1	13	1

Appendix B - Chemical Data

Table 2a. Proximate and sulfur analyses. (All values are in weight percent on a dry, whole-coal basis. Ash temperature=750° centigrade).

Point ID	Ash	Volatile Matter	Fixed Carbon	Sulfate	Pyritic Sulfur	Organic Sulfur
558.01	14.4	42.8	42.8	.63	.60	1.0
558.02	9.3	46.8	43.9	.23	.21	.86
558.09	8.7	46.5	44.8	.11	.11	1.1
558.10	7.1	45.7	47.2	.04	.43	.78
558.11	8.0	45.9	46.2	.04	.11	.99
558.12	52.1	26.8	21.1	.07	.12	.40
558.13	10.0	44.4	45.6	.08	.28	.58
558.14	6.8	43.7	49.5	.07	.08	.48
558.15	7.1	42.4	50.5	.05	.12	.40
558.16	5.8	45.0	49.2	.06	.15	.37
558.17	7.5	45.9	46.6	.05	.08	.38
558.18	6.6	47.4	46.0	.03	.04	.35
558.19	4.9	45.3	49.8	.03	.04	.23
558.20	4.9	45.3	49.7	.03	.11	.16
558.21	5.8	44.1	50.1	.04	.13	.21
558.22	6.1	45.9	48.1	.01	.04	.24
558.23	5.6	41.5	52.9	.03	.10	.17
558.24	5.6	46.5	47.9	.04	.12	.19
558.25	3.5	42.1	54.4	.03	.08	.21
558.26	5.4	46.7	47.9	.04	.15	.25
558.27	7.6	42.8	49.6	.03	.07	.21
558.28	11.1	41.4	47.6	.04	.04	.35
558.29	7.8	40.3	52.0	.03	.06	.21
558.30	4.6	42.4	53.0	.03	.07	.11
558.31	3.7	45.6	50.8	.03	.10	.08
558.32	3.8	44.4	51.8	.01	.06	.11
558.33	5.1	44.2	50.7	.01	.16	.16
558.34	7.0	48.6	44.5	.04	.15	.29
558.35	73.6	18.3	8.1	.08	.10	.10

Table 2b. X-ray fluorescence analyses. (All values are reported on an ash basis except for P_2O_5 and Cl, which are reported on a whole-coal basis. L=less than the value shown.)

Pointid	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	K_2O (%)	TiO_2 (%)	SO_3 (%)	P_2O_5 (%)	Cl (ppm)
558.01	34.7	19.2	13.1	8.1	.79	.62	16.6	.01L	200
558.02	31.0	15.3	7.5	15.5	.41	.61	30.1	.06	400
558.09	26.1	16.0	8.1	17.3	.34	1.5	30.8	.01L	100L
558.10	26.1	14.9	3.3	19.3	.38	.72	32.0	.07	100
558.11	28.5	16.2	3.0	18.0	.37	.56	27.7	.08	100L
558.12	64.1	23.1	.8	2.2	.71	1.6	2.9	.01L	100L
558.13	31.4	19.8	5.3	16.7	.30	.67	26.6	.14	100L
558.14	27.0	15.6	3.4	22.6	.34	.53	22.8	.01L	100L
558.15	25.5	14.6	2.9	24.6	.19	.58	24.4	.03	100
558.16	18.1	15.8	5.1	26.6	.35	.48	27.8	.01L	100
558.17	27.4	15.9	2.6	22.9	.30	1.1	20.8	.01L	100
558.18	21.8	15.9	1.4	24.8	.22	1.8	21.4	.01L	300
558.19	18.8	15.2	2.1	30.2	.40	.96	19.4	.01L	300
558.20	17.7	17.1	3.5	29.6	.26	.85	22.7	.01L	300
558.21	18.8	16.2	3.9	27.8	.39	.74	22.7	.01L	400
558.22	22.7	16.2	1.9	25.0	.28	3.0	15.2	.01L	700
558.23	20.6	18.0	3.1	26.6	.25	.95	18.9	.05	300
558.24	25.7	13.5	3.4	26.2	.45	.68	18.6	.01L	700
558.25	10.4	15.6	3.8	31.3	.42	.71	26.8	.01L	200
558.26	21.9	14.7	5.2	24.6	.38	.74	25.5	.01L	300
558.27	41.1	15.4	2.4	19.3	.20	1.1	12.4	.04	200
558.28	36.4	26.4	1.9	14.0	.41	1.7	11.4	.32	100L
558.29	28.5	18.5	2.7	22.4	.44	1.2	12.3	.35	100
558.30	20.4	14.6	4.5	30.3	.30	.60	16.6	.05	100L
558.31	14.8	12.6	5.7	33.1	.34	.48	20.0	.01L	100L
558.32	18.5	14.8	4.8	30.3	.39	.52	16.2	.01L	100L
558.33	23.4	13.6	6.3	25.8	.37	.70	23.4	.01L	100
558.34	32.4	15.7	5.2	18.7	.39	1.1	17.8	.04	200
558.35	61.2	27.8	1.7	.9	1.6	.99	1.1	.14L	300L

Table 2c. Wet chemical analyses. All values are reported on an ash basis except for F and Hg, which are reported on a whole-coal basis. L=less than the value shown.)

Pointid	Ash (%)	MgO (%)	Na_2O (%)	Li (ppm)	Cu (ppm)	Zn (ppm)	Cd (ppm)	Pb (ppm)	Mn (ppm)	F (ppm)	Hg (ppm)
558.01	14.2	1.8	.19	27	100	180	.80	53	100	300	.060
558.02	10.0	3.3	.31	17	97	93	.60	55	170	50	.020
558.09	8.0	3.5	.31	20	260	140	.70	62	200	100	.130
558.10	7.1	3.8	.32	16	120	76	.40	55	170	100	.005L
558.11	7.5	3.5	.31	20	190	100	.74	53	140	100	.005L
558.12	51.7	0.7	.11	30	170	40	.30	44	46	300	.010
558.13	9.4	2.8	.19	42	130	53	.30	60	150	70	.070
558.14	6.7	4.1	.26	42	76	56	.30	49	200	70	.005L
558.15	6.4	4.5	.24	46	91	65	.40	52	210	40	.005L
558.16	5.3	5.1	.27	71	230	70	.44	64	160	50	.005L
558.17	7.1	5.5	.30	34	76	61	.40	64	210	70	.005L
558.18	6.3	6.1	.28	70	330	70	.44	85	150	70	.005L
558.19	4.9	6.0	.34	36	170	110	.74	66	160	70	.005L
558.20	5.2	5.5	.32	34	130	72	.40	93	140	40	.005L
558.21	5.2	5.3	.32	44	120	58	.30	51	160	200	.005L
558.22	6.0	4.8	.28	73	390	73	.40	66	160	100	.005L
558.23	5.3	4.6	.32	54	240	58	.30	49	150	100	.005L
558.24	5.4	5.1	.34	22	120	73	.40	78	280	100	.005L
558.25	3.4	5.8	.51	9	110	89	.50	58	220	200	.005L
558.26	5.2	4.5	.31	10	110	52	.30	64	230	50	.005L
558.27	6.6	3.6	.28	30	110	49	.30	54	160	100	.005L
558.28	10.3	2.5	.20	27	190	48	.30	62	110	200	.005L
558.29	7.2	3.8	.28	24	130	58	.32	61	170	100	.005L
558.30	4.2	5.5	.45	15	73	76	.40	47	160	50	.005L
558.31	3.7	6.6	.54	8	75	88	.50	64	160	100	.005L
558.32	4.0	5.8	.51	8	89	82	.50	72	140	100	.005L
558.33	5.0	4.8	.39	13	140	98	.60	52	120	50	.005L
558.34	6.8	3.6	.35	13	130	62	.40	65	100	50	.005L
558.35	73.0	0.8	.14	38	100	81	.50	45	23	700	.005L

Table 2d. Optical emission spectrographic analyses. (All values are in ppm on an ash basis. L=less than the value shown; H=unresolved interference in the analysis.)

ID	Ag	Au	B	Ba	Be	Bi	Dy	Er	Ga	Gd	Ge	Ho	In	Ir	Mo	Nb
558.01	.47	6.8L	420	740	26.0L	22L	26	21.0	84	22L	27.0	10.0	6.8L	10L	34	16
558.02	.20	6.8L	470	1900	28.0	22L	37	29.0	26	50	4.6L	9.6	6.8L	10L	23	17
558.09	.56	6.8L	840	2300	8.0	22L	10L	4.6L	35	22L	4.6L	7.2	6.8L	10L	25	13
558.10	.66	6.8L	950	4100	7.3	22L	10L	4.6L	32	22L	4.6L	3.7	6.8L	10L	25	9
558.11	.87	6.8L	920	3900	9.9	22L	10L	10.0L	53	22L	4.6L	4.4	6.8L	10L	30	41
558.12	.55	6.8L	110	710	1.5L	22L	10L	4.6L	38	22L	4.6L	1.5L	6.8L	10L	11	38
558.13	.41	6.8L	660	6800	8.3	22L	10L	4.6L	32	22L	4.6L	4.1	6.8L	10L	16	18
558.14	.21	6.8L	940	5000	4.9	22L	10L	4.6L	24	22L	4.6L	10.0L	6.8L	10L	11	19
558.15	.24	6.8L	850	3800	5.4	22L	10L	4.6L	24	22L	4.6L	10.0L	6.8L	10L	12	28
558.16	.19	6.8L	610	4600	2.8	22L	10L	4.6L	24	22L	4.6L	1.5L	6.8L	10L	17	25
558.17	.71	6.8L	690	3300	1.5L	22L	10L	4.6L	35	22L	4.6L	6.8L	6.8L	10L	10	25
558.18	.88	6.8L	700	3300	1.5L	22L	10L	4.6L	57	22L	4.6L	1.5L	6.8L	10L	10	36
558.19	.35	6.8L	770	4100	1.5L	22L	10L	4.6L	46	22L	4.6L	1.5L	6.8L	10L	11	21
558.20	.33	6.8L	950	4700	1.5L	22L	10L	4.6L	44	22L	4.6L	5.1	6.8L	10L	16	70
558.21	.52	6.8L	940	6400	1.5L	22L	10L	4.6L	56	22L	4.6L	1.5L	6.8L	10L	11	41
558.22	.61	6.8L	740	4200	1.5L	22L	10L	4.6L	65	22L	4.6L	10.0L	6.8L	10L	9	45
558.23	.36	6.8L	980	6700	2.8	22L	10L	4.6L	39	22L	4.6L	10.0L	6.8L	10L	12	18
558.24	.32	6.8L	980	4000	2.1	22L	10L	4.6L	22	22L	4.6L	10.0L	6.8L	10L	10	27
558.25	.42	6.8L	710	4000	1.5L	221	101	4.6L	27	22L	4.6L	1.5L	6.8L	10L	23	16
558.26	.38	6.8L	940	4200	1.5L	22L	10L	4.6L	25	22L	4.6L	1.5L	6.8L	10L	11	25
558.27	.36	6.8L	790	4400	2.5	22L	10L	4.6L	30	22L	4.6L	1.5L	6.8L	10L	17	41
558.28	.51	6.8L	540	6600	3.5	22L	10L	4.6L	67	22L	5.1	10.0L	6.8L	10L	15	110
558.29	.86	6.8L	740	13000	3.4	22L	10L	4.6L	51	22L	4.6L	10.0L	6.8L	10L	12	34
558.30	.27	6.8L	580	8800	3.2	22L	10L	4.6L	20	22L	4.6L	1.5L	6.8L	10L	19	32
558.31	.42	6.8L	580	8700	2.5	22L	10L	4.6L	25	22L	4.6L	10.0L	6.8L	10L	22	37
558.32	.98	6.8L	580	8700	2.1	22L	10L	4.6L	23	22L	4.6L	10.0L	6.8L	10L	23	24
558.33	.51	6.8L	580	7000	3.5	22L	10L	4.6L	24	22L	4.6L	1.5L	6.8L	10L	29	33
558.34	.93	6.8L	740	8200	5.6	22L	10L	4.6L	62	22L	5.1	1.5L	6.8L	10L	17	28
558.35	.63	6.8L	94	1100	2.9	22L	10L	4.6L	47	22L	4.6L	10.0L	6.8L	10L	12	40

Table 2d. (Continued)

ID	Nd	Ni	Os	Pd	Pr	Pt	Re	Rh	Ru	Sn	Sr	Tl	Tm	V	Y	Zr
558.01	79	220	10L	.68L	12.0	2L	10L	1.5L	1L	11.0	1200	10L	3.2L	320	160	280
558.02	170	120	10L	.68L	38.0	2L	10L	1.5L	1L	35.0	2500	10L	3.2L	130	210	320
558.09	200	160	10L	.68L	39.0	2L	10L	1.5L	1L	25.0	3500	10L	3.2L	200	120	340
558.10	140	91	10L	.68L	22.0	2L	10L	1.5L	1L	4.6L	3900	10L	3.2L	210	98	380
558.11	130	69	10L	.68L	23.0	2L	10L	1.5L	1L	8.2	4800	10L	3.2L	350	98	550
558.12	42	39	10L	.68L	6.8L	2	10L	1.5L	1L	9.5	310	10L	3.2L	210	25	260
558.13	32L	82	10L	.68L	8.6	2L	10L	1.5L	1L	6.7	5000	10L	3.2L	160	56	400
558.14	150L	77	10L	.68L	18.0	2L	10L	1.5L	1L	8.5	4300	10L	3.2L	130	57	410
558.15	150L	99	10L	.68L	16.0	2L	10L	1.5L	1L	11.0	4900	10L	3.2L	140	69	460
558.16	150L	89	10L	.68L	24.0	2L	10L	1.5L	1L	4.6L	5500	10L	3.2L	170	64	500
558.17	150L	50	10L	.68L	6.8L	2L	10L	1.5L	1L	12.0	4200	10L	3.2L	180	47	540
558.18	150L	67	10L	.68L	17.0	2L	10L	1.5L	1L	18.0	4600	10L	3.2L	280	40	500
558.19	150L	57	10L	.68L	9.8	2L	10L	1.5L	1L	19.0	4800	10L	3.2L	210	37	500
558.20	150L	49	10L	.68L	6.8L	2L	10L	1.5L	1L	16.0	5200	10L	3.2L	180	37	570
558.21	150L	51	10L	.68L	10.0	2L	10L	1.5L	1L	12.0	4800	10L	3.2L	200	28	420
558.22	150L	39	10L	.68L	6.8L	2L	10L	1.5L	1L	36.0	5000	10L	3.2L	500	34	480
558.23	150L	40	10L	.68L	15.0	2L	10L	1.5L	1L	19.0	5900	10L	3.2L	300	44	490
558.24	150L	47	10L	.68L	17.0	2L	10L	1.5L	1L	35.0	4700	10L	3.2L	120	53	560
558.25	150L	39	10L	.68L	6.8L	2L	10L	1.5L	1L	22.0	7300	10L	3.2L	170	38	370
558.26	150L	38	10L	.68L	14.0	2L	10L	1.5L	1L	16.0	4700	10L	3.2L	140	45	470
558.27	150L	37	10L	.68L	13.0	2L	10L	1.5L	1L	23.0	4400	10L	3.2L	170	61	770
558.28	150L	42	10L	.68L	21.0	2L	10L	1.5L	1L	13.0	4900	10L	3.2L	340	48	980
558.29	150L	39	10L	.68L	20.0	2L	10L	1.5L	1L	12.0	9500	10L	3.2L	210	57	540
558.30	0H	110	10L	.68L	24.0	2L	10L	1.5L	1L	4.6L	5300	10L	3.2L	180	110	560
558.31	0H	180	10L	.68L	6.8L	2L	10L	1.5L	1L	4.6L	7100	10L	3.2L	170	59	460
558.32	0H	120	10L	.68L	28.0	2L	10L	1.5L	1L	4.6L	5400	10L	3.2L	200	56	440
558.33	0H	170	10L	.68L	17.0	2L	10L	1.5L	1L	4.6L	5500	10L	3.2L	200	58	610
558.34	150L	130	10L	.68L	6.8L	2L	10L	1.5L	1L	18.0	5500	10L	3.2L	200	64	560
558.35	55	47	10L	.68L	6.8L	2L	10L	1.5L	1L	8.7	330	10L	3.2L	310	29	340