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Whole-Rock Chemical Composition of Some Samples from Two Drill Hole Cores in the Capps Coal Field, Beluga Coal Area, South-Central Alaska

By

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

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WHOLE-ROCK CHEMICAL COMPOSITION OF SOME SAMPLES FROM TWO DRILL HOLE CORES IN THE CAPPS COAL FIELD, BELUGA COAL AREA, SOUTH-CENTRAL ALASKA

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ABSTRACT

Whole-rock chemical analysis was done on samples from drill cores of rocks lying atop and between coal beds in the Beluga coal area, south-central Alaska. The samples were classified as sandstone, siltstone or claystone at time of hand specimen description. Chemical data were compared to those from corresponding rocks from other sites in the conterminous United States.

The study supports the following conclusions:

1. The sample suites from the two cored Alaska holes, about 1 km apart, contrast sharply in their degree of lithologic differentiation, one having relatively purer sandstones and claystones, the other having more mixed rock types. This suggests that considerable variation occurs in depositional environments and, possibly, in rock chemistry over small distances in the Beluga coal area.

2. Hand specimen inspection is a reasonably reliable way of assigning names denoting the lithologic type of Alaska rocks, and thereby making broad predictions of their whole-rock chemisty.

3. In both Alaska suites the fine-grained rocks (claystones) contain more of a large group of trace elements, up to a factor of two or more, than the coarse-grained rocks (sandstones). There are, however, contrasts between comparable rock types of the two Alaska suites. The sandstones of the less differentiated Alaska suite (1980) contain as much as 50 percent more of a suite of major and minor rock-forming elements (Al, Ca, K, Fe, Mg, and Ti) than those of the other (1979) suite. The fine-grained rocks of the less differentiated 1980 Alaska suite have smaller amounts of Ca, Fe and Mg than the 1979 Alaska suite. K and Ti have similar values in the two Alaska suites, and Al has a slightly higher value in the less differentiated suite.

4. For the elements of greatest environmental concern in the coal regions of the United States, B, Na and Mo, the Beluga coal area rocks compare with those of other sites in the following ways: the mean concentrations of B in the Alaska rocks are similar to those in most other sites except for the Tertiary Ft. Union Formation suite from Montana, Wyoming, and North Dakota, in which the mean is much larger; the mean of Na in Alaska rocks is comparable to that of other suites except the suite of relatively well-differentiated rocks of Cretaceous age, from Wyoming, Utah, and Colorado, which has a much smaller mean; mean concentrations of Mo in the Alaska rocks are similar to those of other sites, except that the fine-grained rocks of the Tertiary Ft. Union Formation have much larger concentrations.

For the other elements commonly cited as of environmental interest, Co, Cr, Cu, Ni, Pb, V, and Zn, the following comparisons can be made: the mean concentration values of Co and Cr in fine- or coarse-grained Alaska rocks are not larger than the largest mean value among similar rock suites from other sites: Ni and V in fine-grained Alaska rocks have the largest mean values of similar rock suites; Cu, Pb and Zn in both fine- and coarse-grained Alaska rocks have the largest mean values among similar rock suites.

5. Individual Alaska samples which have relatively high concentrations of several minor and trace elements bear no clear spatial relationship to major units of rock or coal in the stratigraphic interval sampled. However, several of the high-concentration samples are dark gray to black in color, may contain lignitic material, were identified as claystones, and were massive (without bedded structure). The less differentiated 1980 Alaska suite contains fewer samples with noticeably higher elemental concentrations than the 1979 suite. Some samples may owe their high concentrations to contamination during drilling.

6. Greater predictive power about the long-range, postmining potential for chemical release from the Alaska rocks can come from further investigations of a) mineral composition of the rocks, b) the amounts of elements removed from the rocks by solution leaching experiments, and c) the temperature, moisture, and vegetation regimes to which the rocks would be exposed after disturbance.

GENERAL STATEMENT

Samples representing rocks overlying and between coal beds were taken from two continuous drill hole cores, approximately 1 km apart, in the Capps coal field of the Beluga coal area of south-central Alaska. Chemical analyses of the samples were done for two purposes. The first was to find out whether any of the rock material had unusually high contents of chemical elements of environmental concern. The chemical analyses were compared to those of rocks in areas with similar geology, weathering regime, and mining opportunities. The second purpose was to find out whether relatively benign rock material could be distinguished in some clear and simple way, such as by visual inspection, from relatively hazardous material without expensive analyses.

GEOLOGY AND LOCATION OF SAMPLING SITES

Preliminary regional and geologic maps are presented in figures 1 and 2. Figure 2 (from Chleborad and others, 1982, to which paper the reader is referred) shows the locations of the cored holes.

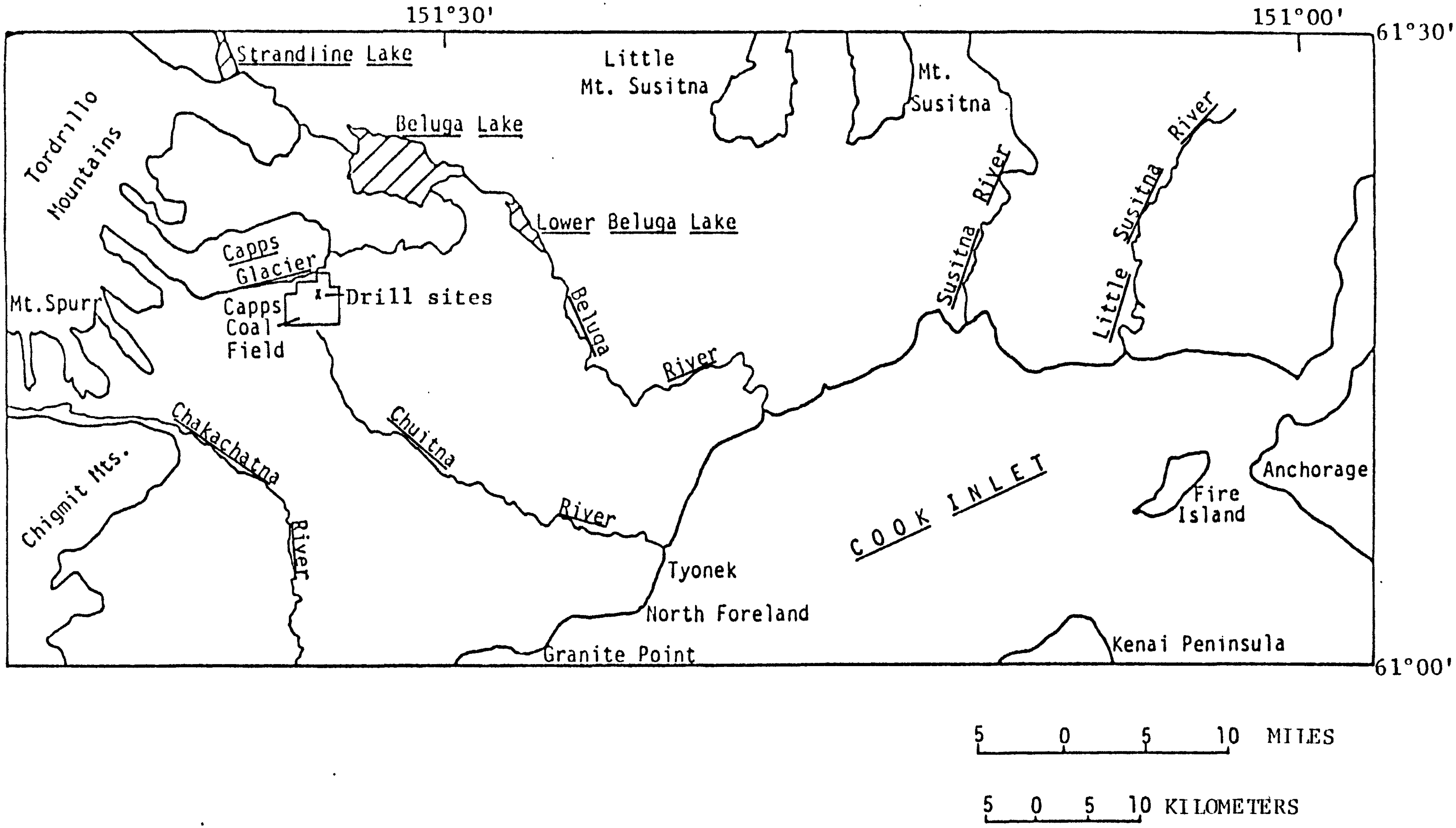


Figure 1.--Regional map showing the location of Capps coal field and the drill sites (from Chleborad and others, 1980).

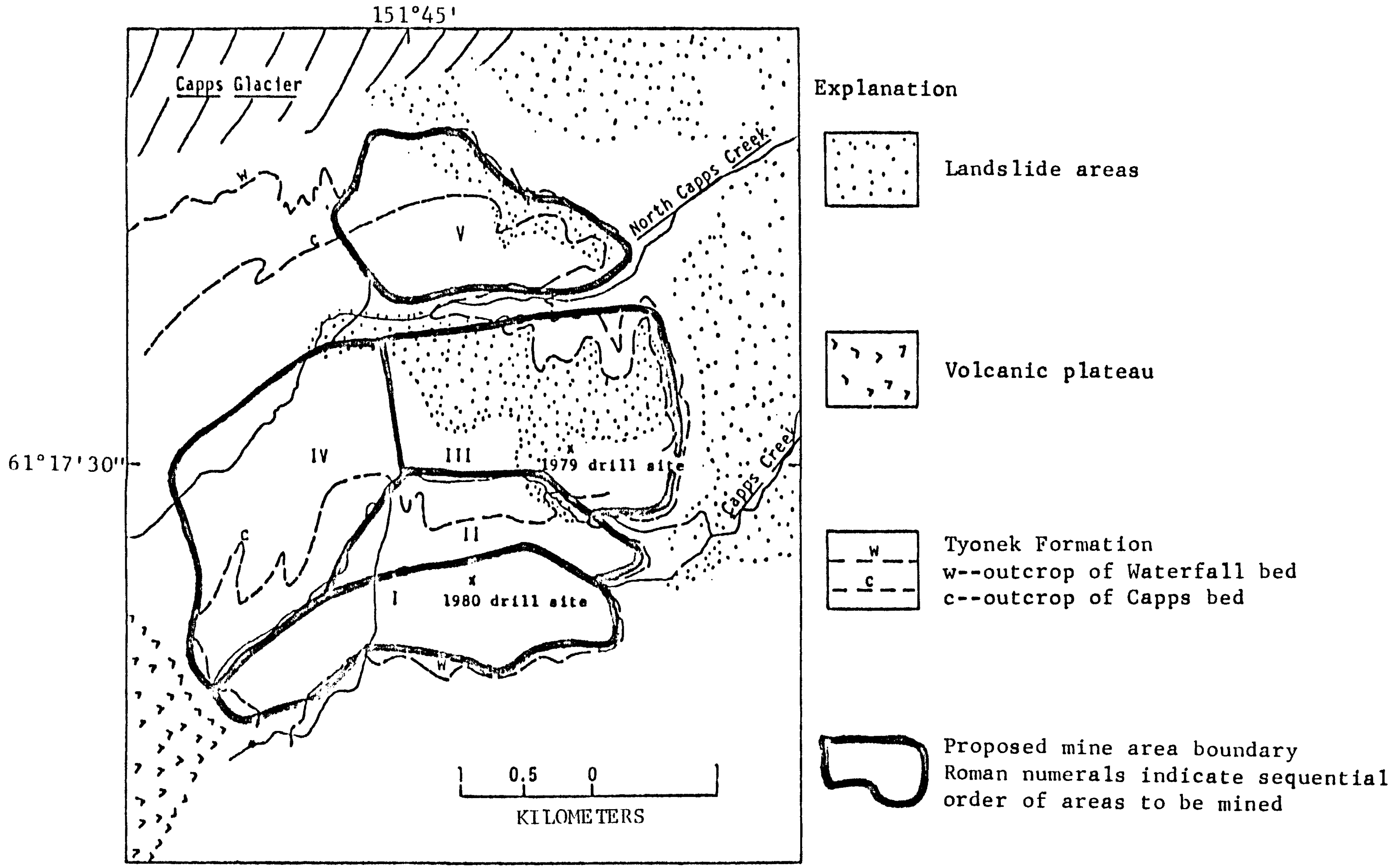


Figure 2.--Locations of the 1979 and 1980 cored holes in the Capps coal field, Alaska. Geology and proposed mine areas are shown (from Chleborad and others, 1982).

STRATIGRAPHY AND LITHIC COMPOSITION

OF THE DRILL CORE SAMPLES

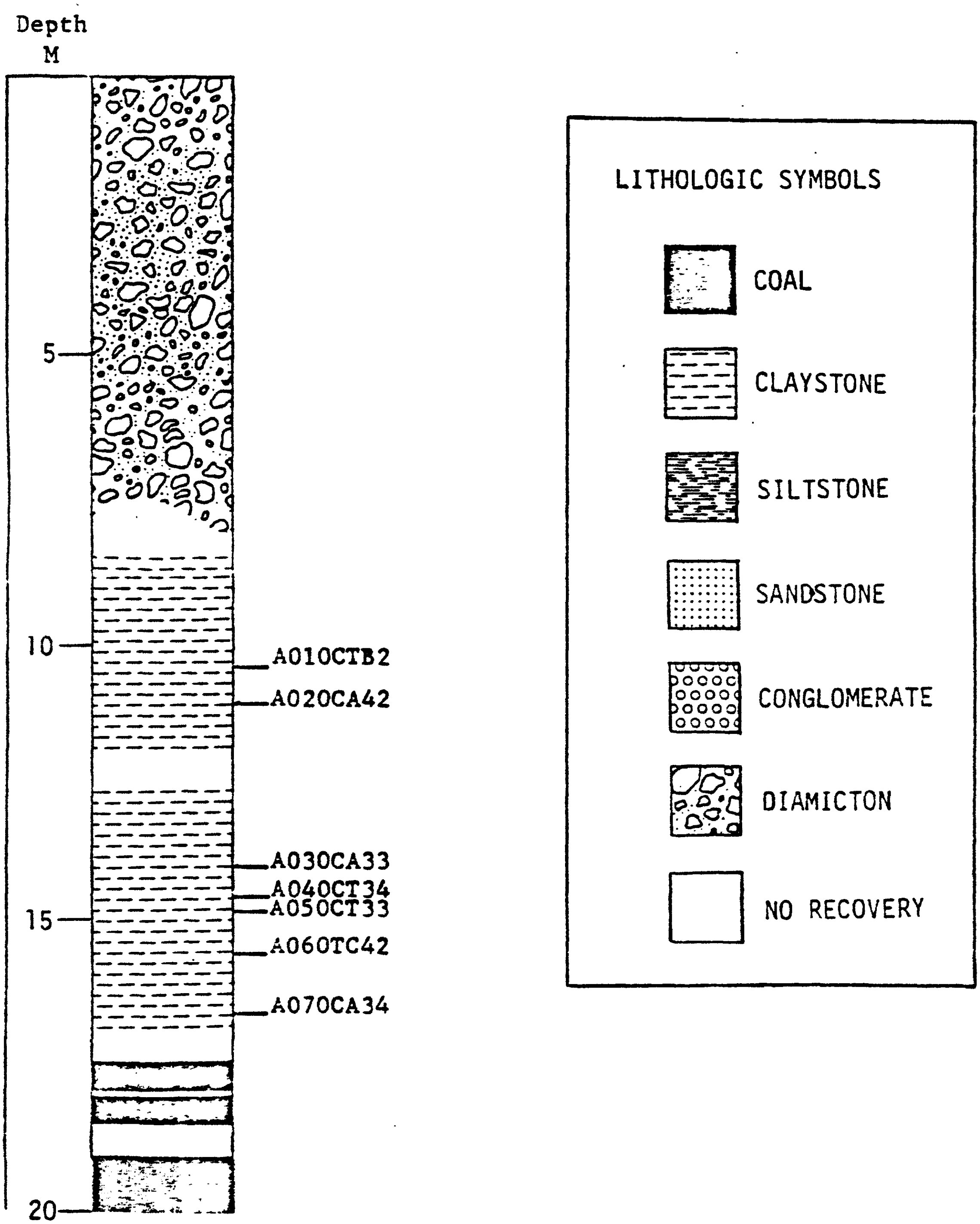
Figure 3 (after Chleborad and others, 1980· and Chleborad and others, 1982) presents the stratigraphy and detailed lithologic composition of the two sampled cores. In the figure, by means of a dashed leader-line, we have schematically linked the two multiple-layered coal beds called the Waterfall bed at both drill holes. We have marked the location of each analyzed sample at the appropriate depth alongside the diagram of each core, according to identification code of each sample, as explained in the Appendix.

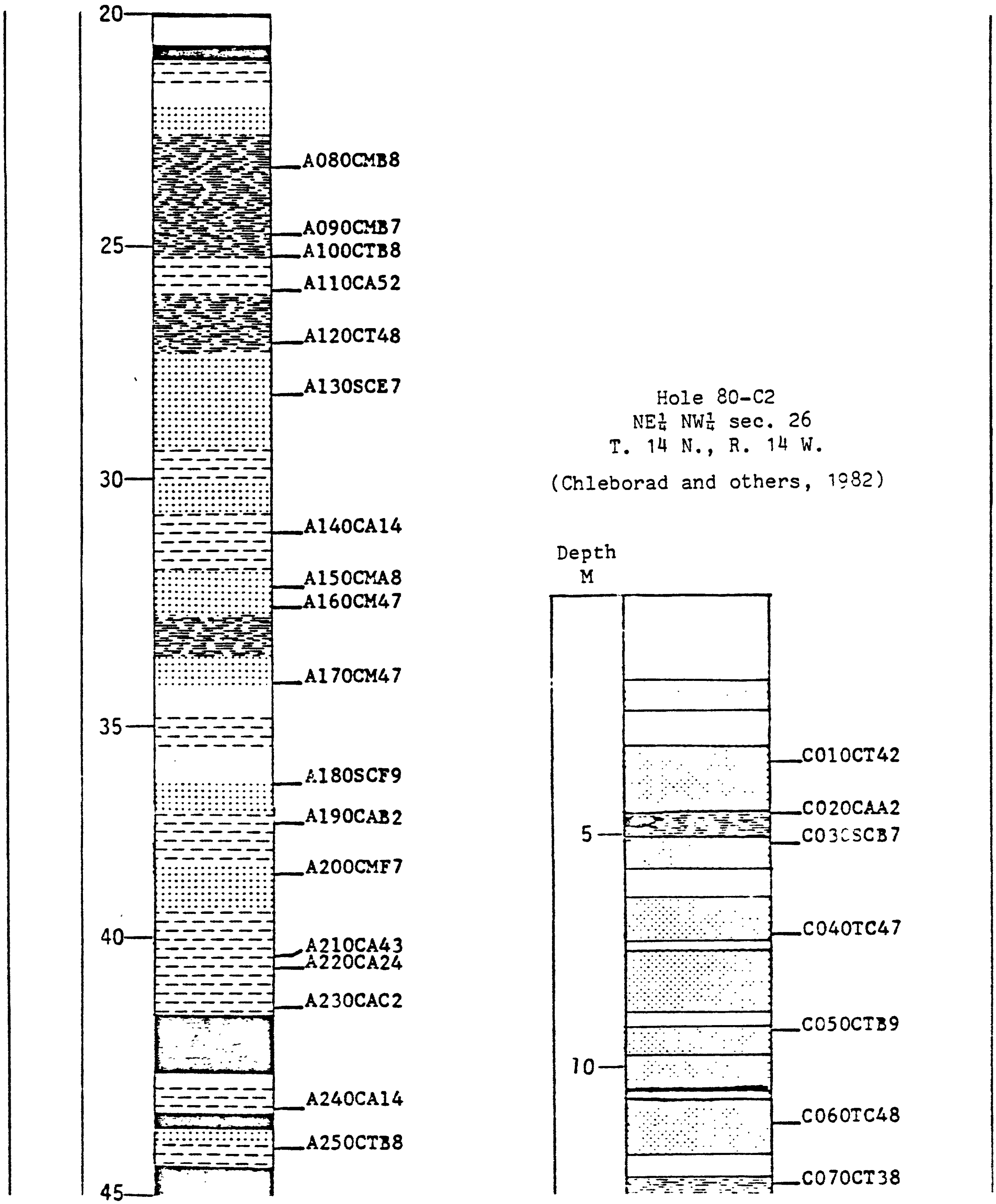
The section diagrams were based, by Chleborad and colleagues, upon their classification of the rocks in the field. Subsequent laboratory particle size determinations by them indicate that some claystone units are in fact siltstone. Also, the rock names assigned by the authors of this report may, for some samples, not coincide with the original or revised rock name assignments of Chleborad and colleagues.

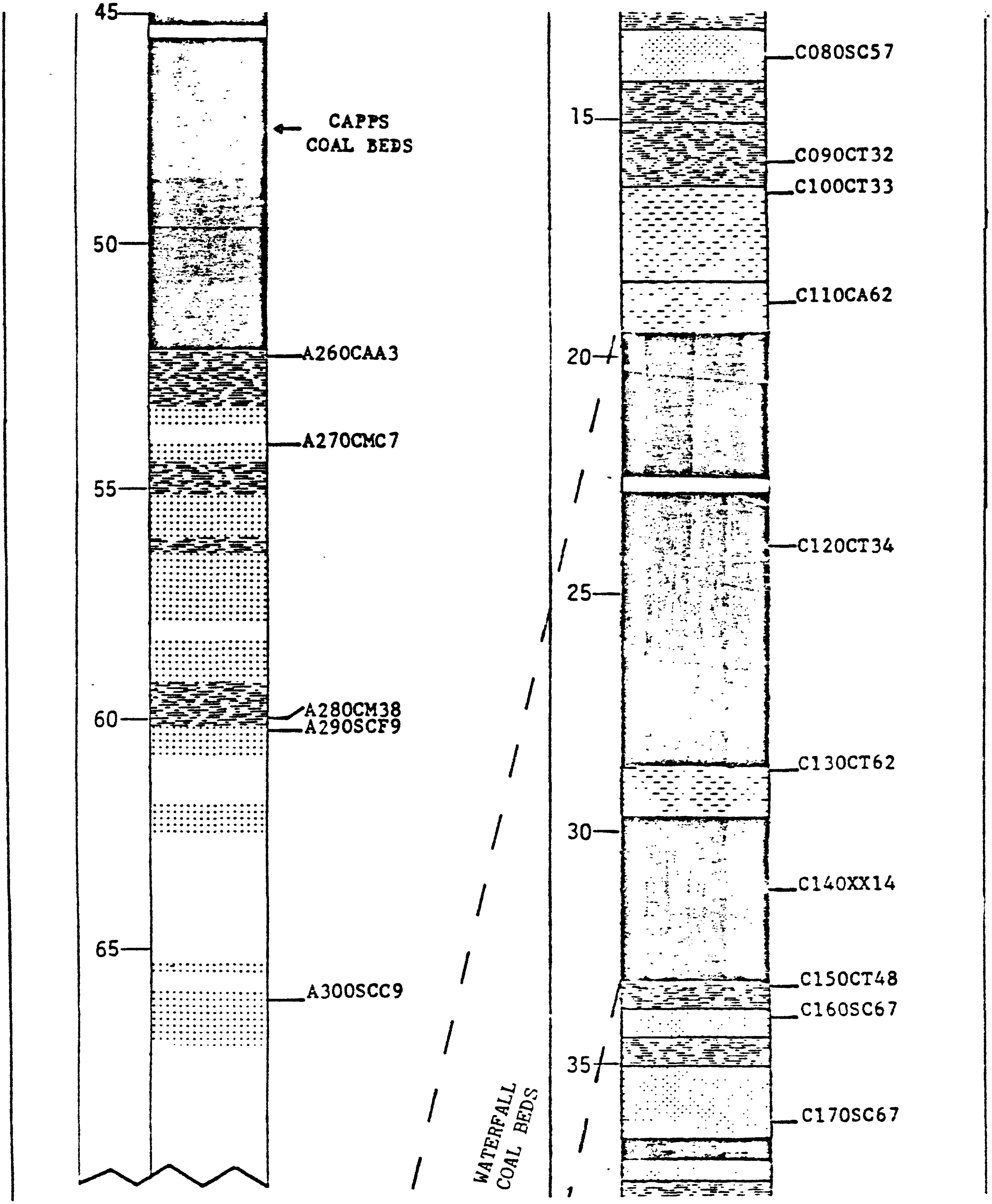
Figure 3.--Graphical stratigraphic logs of the 1979 and 1980 cored holes, Capps coal field, Tyonek (B-5) quadrangle, Alaska. Sample locations with sample numbers are shown. The section diagrams were based on work by Chleborad and colleagues. The following four pages fit together end to end, forming vertical columns.

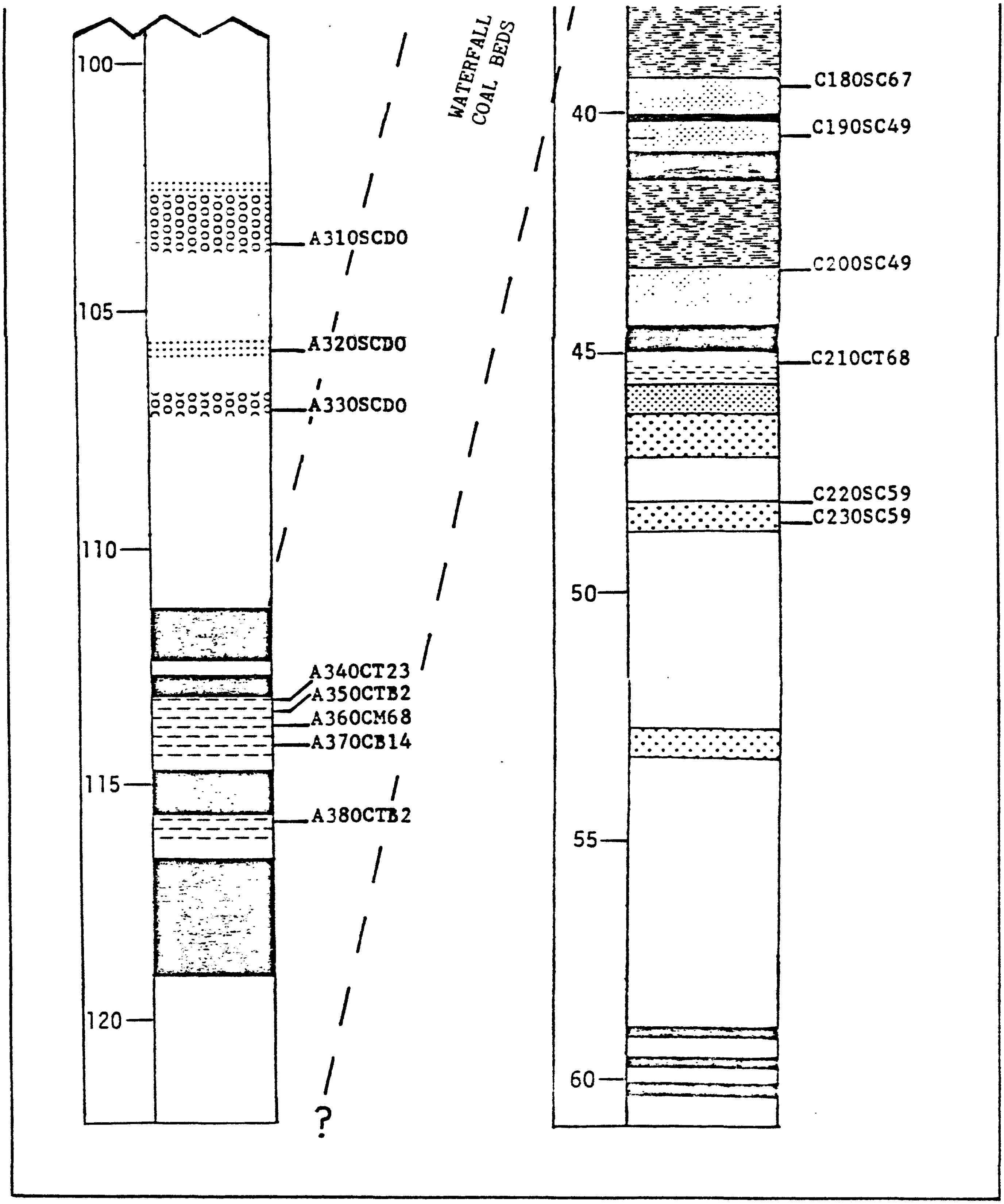
Hole 79-C1
Center NE¼ sec. 23
T. 14 N., R. 14 W.

(Chleborad and others, 1980)




20
25
30
35
40
45
A080CMB8
A090CMB7
A100CTB8
A110CA52
A120CT48
A130SCE7
A140CA14
A150CMA8
A160CM47
A170CM47
A180SCF9
A190CAB2
A200CMF7
A210CA43
A220CA24
A230CAC2
A240CA14
A250CTB8
Hole 80-C2
NE¼ NW¼ sec. 26
T. 14 N., R. 14 W.
(Chleborad and others, 1982)
Depth
M
5
10
C010CT42
C020CAA2
C030SCB7
C040TC47
C050CTB9
C060TC48
C070CT38


45
50
55
60
65
CAPPS
COAL BEDS
A260CAA3
A270CMC7
A280CM38
A290SCF9
A300SCC9
15
20
25
30
35
C080SC57
C090CT32
C100CT33
C110CA62
C120CT34
C130CT62
C140XX14
C150CT48
C160SC67
C170SC67
WATERFALL
COAL BEDS



WATERFALL COAL BEDS
100
105
110
115
120
A310SCD0
A320SCD0
A330SCD0
A340CT23
A350CTB2
A360CM68
A370CB14
A380CTB2
?
40
45
50
55
60
C180SC67
C190SC49
C200SC49
C210CT68
C220SC59
C230SC59

SYSTEMATICS AND LIMITATIONS OF CHOICE OF SAMPLES

Samples, already separated from the whole core, were delivered to us at field moisture content. The details of history and preparation of the cores can be found elsewhere (Chleborad and others, 1980: Chleborad and others, 1982). The core segments constituting the provided samples were of shorter and less consistent length than many of the samples from earlier studies by us at other sites, which form a basis of comparison for the data of this study (Hinkley and others, 1978: Hinkley, Herring, and Ebens, 1980; Hinkley and others, 1980a; Hinkley and others, 1980b: Gough and Severson, 1982; Herring and others, 1982).

Some of the softer samples could be contaminated by drilling mud or other contaminants. However, our colleagues who were present during drilling at the field site state that they believe that the appearances of cored rock and drilling mud are sufficiently distinct to rule out ambiguity or problem in this respect (C. A. Gardner, U.S. Geological Survey, oral commun., 1982).

We did not see the entire continuous core. By the time we received them, many samples were deformed from their original cylindrical-segment shape, or even more extensively physically disturbed. Therefore, we cannot give a confident lithologic description of the rock column on broad and fine scales, as we were better able to do in the similar geochemical studies at other sites. We wish the reader to be aware of our doubts deriving from the lack of continuity in our control of sampling procedures. At this time we can present no evidence to aid the reader in assessing the merits of our precautionary statements.

CLASSIFICATION OF SAMPLES INTO ROCK TYPES

Samples were classified by lithologic type, as identifiable by quick, simple tests and by appearance in hand specimen. This classification was done to determine whether the different rock types had distinctive chemistry; if so, the chemistry might be predicted from hand specimen observation in future work, thereby avoiding considerable delay and analytical expense.

The samples were classified into the following groups:

1. Sandstone (grain size greater than 0.2 mm, approximately)
2. Siltstone (grain size visible by hand lens, 0.2 mm or smaller)
3. Claystone (shale and other very fine grained rocks)

Individual samples appeared to be most commonly of mixed type. The rocks were described in greater detail than simply by their broad rock type name. Additional information given is whether the rock sample is a pure or mixed type; if mixed, the lithologic nature of the admixture (sandy, silty or clayey); the depth in the drill core; the color of the sample. These properties are coded into the sample identifier label, explained in the Appendix. Still more information on each sample, recorded as hand specimen descriptions (details of texture, fine-scale layering, presence of organic material, reaction to dilute acid, degree and rapidity of physical degradation during immersion in water), is unpublished data.

ANALYTICAL PROCEDURES AND ANALYTICAL PROBLEMS

Values for SiO_2, Al_2O_3, Fe (as Fe_2O_3), MgO, CaO, K_2O, TiO_2, and P_2O_5 were obtained by X-ray fluorescence spectrometry. This is a precise and accurate method and was applied uniformly to the 1979 and 1980 sample suites (Taggart and others, 1981).

Data for all other elements were obtained by semiquantitative spectrographic methods. The 1979 core, and all of the samples from other sites used for comparison, were analyzed by old-style plate-reader or 6-step emission spectroscopy (Myers and others, 1961). The 1980 core was analyzed by the more modern induction-coupled plasma optical emission spectroscopy (ICP) (Scott and Kokot, 1975; Floyd and others, 1980; Taggart and others, 1981). The data reported from analyses by these two techniques have systematic differences, of varying degree for different elements. Unfortunately, the two analytical methods are not sufficiently precise to allow a systematic correction to bring the data of one technique into line with those of the other. We wish the reader to be aware of this difficulty.

The samples were analyzed in random order so that systematic error (such as "machine drift") through the analytical sequence is converted to random error. The 1979 core has a total of 48 samples, including 10 random analytical duplicate splits, and the 1980 core has a total of 33 samples, including 10 random analytical duplicate splits.

ANALYTICAL DUPLICATION AND ANALYTICAL ERROR

A fraction of the samples in both the 1979 and 1980 Alaska suites was randomly chosen to be split after grinding and was analyzed in duplicate. The placement of such splits within the analytical sequence was random, and their identity was unknown to the analysts. In the Appendix, the paired samples are placed together to facilitate comparison of their corresponding analytical values: sample pairs may be identified by their having identical code numbers, except for different fourth-column characters, which are either "O" for original sample or "X" for analytical split.

In general, the precision (consistency) of reported concentrations within pairs of split samples is excellent for major and minor rock-forming elements for both the 1979 and 1980 Alaska sample suites. For the trace elements the precision was poorer in the 1979 Alaska suite, which was analyzed by plate-reader emission spectroscopy; the differing values for duplicate pairs in some cases result in uncertainty as to whether a sample is in a normal or abnormal concentration range for a particular element. Such discrepancies are discussed below where a few special samples are individually treated in detail (see Discussion of Some Individual Alaska Samples section of this paper). Trace element pairs in the 1980 Alaska suite, which was analyzed by the newer ICP method, have better precision in most cases.

DIFFERENCES IN COMPOSITION
OF MAJOR AND MINOR ROCK-FORMING ELEMENTS
IN ROCKS FROM THE TWO CORED HOLES

The rocks from the northeast (1979) hole are the more differentiated suite: the sandstones have a higher content and the claystones a lower content of SiO_2 than the corresponding rocks from the southwest (1980) hole. This contrast is presented in figure 4.

The sandstones of the northeast (1979) hole average about 82 percent SiO_2 (range 71-90 percent). Those from the southwest hole (1980) average about 69 percent SiO_2 (range 64-75 percent). The fine-grained rocks from the northeast hole average about 60 percent SiO_2 (range 42-70 percent), those from the southwest hole average about 63 percent (range 54-76 percent).

There are distinct contrasts between comparable rock types from the two holes in their contents of other rock-forming elements such as Al, Ca, K, Fe, Mg, and Ti. The sandstones of the less differentiated suite from the 1980 hole contain more of those elements, by as much as 50 percent, than do those from the 1979 hole. This suggests the presence of more dark and opaque minerals, as well as some combination of clay and feldspar minerals.

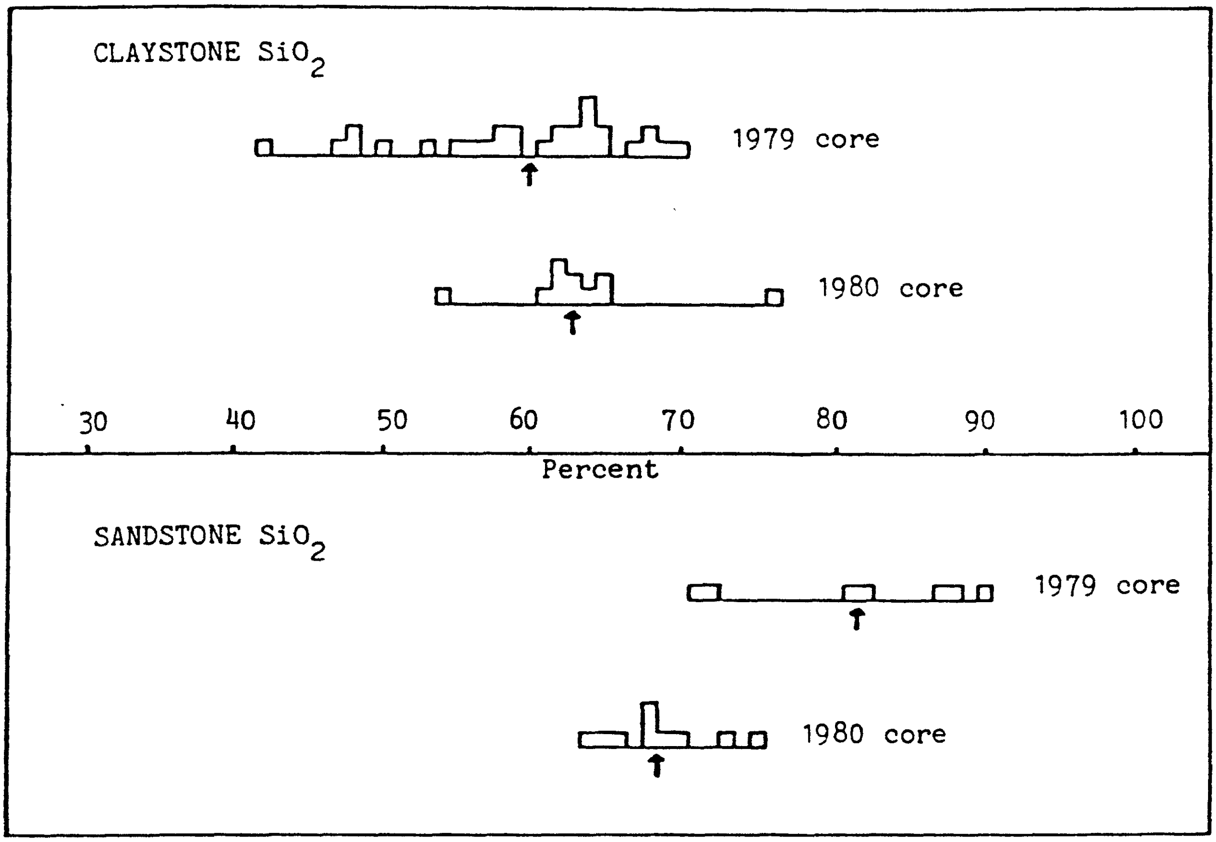


Figure 4.--Frequency distributions and arithmetic means (arrows) for SiO_2 contents of sandstone and claystone in the 1979 and 1980 suites of Alaska rocks.

The fine-grained rocks in the less differentiated 1980 Alaska suite have smaller amounts of Ca, Fe and Mg than the 1979 Alaska suite. K and Ti have similar values in the two suites and Al has a slightly higher value in the less differentiated suite. Less can be said about the mineralogical meaning of those chemical data for the fine-grained rocks than for the sandstones. The reader is referred to an important study by Schultz and others (1980), in which it was shown that the specific identity of the types of clay and feldspar in a fine-grained rock, as well as their proportions, determine the rock's chemistry with respect to a large number of major and minor rock-forming elements. The possibilities of mineral composition are too broad to allow much inference about the mineral composition to be made from chemical composition data alone.

CHEMISTRY OF BELUGA COAL AREA ROCKS

COMPARED TO OTHER OVERBURDEN ROCKS

In order to assess the Beluga region rocks for reclamation considerations, it is useful to know how their detailed chemistry compares with that of other overburden rocks that have been investigated (Hinkley and others, 1978; Hinkley, Herring, and Ebens, 1980; Hinkley and others, 1980a; Hinkley and others, 1980b; Gough and Severson, 1982; Herring and others, 1982).

The basis of the comparative discussion is the data in tables 1 and 2. The suites of rock samples chosen for comparison are the following:

1. Ft. Union Formation suite. Rocks of this Paleocene age formation overlie deposits of mineable coal in much of North Dakota, Montana, Wyoming, and Utah.

2. Cretaceous age suite. Cretaceous age rocks overlie much mineable coal in Colorado, Utah, New Mexico and parts of Wyoming. Samples from those States, excepting New Mexico, are included in the Cretaceous suite presented in tables 1 and 2.

3. Kimbeto site suite. Rocks of Cretaceous age from this site in northwestern New Mexico are presented separately because the rather undifferentiated nature of the suite is anomalous among the other Cretaceous age suites and because the Alaska suites, especially those from the 1980 drill core, are similarly rather undifferentiated.

4. San Juan Basin mine spoils and topsoils. These materials are included in the tables because of their general relation to reclamation considerations. The reader is cautioned that these materials may or may not be closely related to the Kimbeto site sample suite presented in the tables, and reminded that the weathering regime to which those samples have been exposed in New Mexico is very different from that in Alaska.

Table 1.--Bulk chemical composition of overburden rocks from two drill cores in the Capps coal field, Beluga coal area, south-central Alaska and other selected sites: also topsoils and mine spoil material from the San Juan Basin, N. Mex.

[Values are geometric means (except for some SiO_2 values). "Sand" indicates sandstone, "Silt" indicates siltstone, "Clay" indicates shale and other very fine-grained rocks, as used in the text; "n", number of samples analyzed where the San Juan Basin number of samples includes analytical duplicate splits of all the samples, the Ft. Union sandstones include 10 random analytical duplicate splits, the Ft. Union claystones include 12 random analytical duplicate splits, the Kimbeto site includes a total of 7 random analytical duplicate splits, and the other sites with Cretaceous overburden include a total of 35 random analytical duplicate splits; values for the Alaska suites do not include analytical duplicates; "n.d.", no data available]

Chemical Species	Alaska 1979 Core†		Alaska 1980 Core			Ft. Union overburden		Kimbeto, N. Mex.			Other sites with Cretaceous overburden¶			San Juan Basin	
	Sand n=7	Clay n=29	Sand n=9	Silt n=2	Clay n=11	Sand n=42	Clay n=50	Sand n=27	Silt n=4	Clay n=15	Sand n=110	Silt n=25	Clay n=77	Topsoil n=12	Mine spoil n=12
SiO_2%---	*81.5	*60.2	*68.6	*65.0	*63.4	70.6	57.8	*70.5	*69.8	*62.7	*79.3	*67.3	*59.0	74.9	64.2
Al_2O_3%--	7.8	16.5	15.2	16.6	17.8	11.2	28.3	13.2	15.0	16.4	6.1	10.4	13.7	5.5	11.5
CaO%----	0.47	0.70	0.63	0.60	0.58	2.2	1.7	1.4	0.78	0.81	0.56	1.7	1.4	1.8	2.0
Fe_2O_3%--	1.9	4.4	3.5	4.5	3.4	1.7	4.3	2.5	3.1	4.6	1.2	2.7	3.3	2.0	2.4
K_2O%----	1.9	2.5	2.9	2.7	2.6	1.8	2.6	2.1	2.6	2.7	1.5	2.0	2.1	1.8	1.7
MgO%----	0.62	1.4	0.98	1.1	1.1	1.8	2.3	0.74	0.90	1.2	0.61	1.4	1.5	0.70	0.93
Na_2O%---	1.1	0.86	1.8	1.6	1.0	1.1	0.86	1.8	1.8	1.3	0.13	0.27	0.20	1.6	2.3
TiO_2%---	0.26	0.71	0.59	0.70	0.68	0.43	0.63	0.52	0.54	0.65	0.28	0.57	0.58	0.38	0.45
P_2O_5%---	0.09	0.13	0.11	0.12	0.11	n.d.	n.d.	0.11	n.d.	0.065	n.d.	0.13	0.14	n.d.	n.d.
B ppm---	17.4	26	n.d.	n.d.	n.d.	42	59	13	18	19	14	23	28	6.9	13
Co ppm--	6.8	8.8	6.2	4.1	7.7	11	8.7	8	10	12	4	8	9.3	6.0	8.5
Cr ppm--	35	61	39	66	70	46	72	19	30	30	16	36	43	22	14
Cu ppm--	11	40	23	35	43	14	38	14	37	39	7	22	30	10	18
Mn ppm--	167	302	412	357	303	233	300	183	251	105	75	235	209	260	340
Mo ppm--	2.0	2.3	n.d.	n.d.	n.d.	1.8	6.1	2.3	3.4	2.8	1.8	2.1	2.3	1.8	2.7
Ni ppm--	23	36	24	29	38	26	30	12.3	20	23	9.7	20	27	8.6	12
Pb ppm--	11	20	22	30	37	12	11	9.5	19	16	5.8	9	13	11	11
V ppm---	60	119	71	102	117	75	86	60	81	92	37	79	91	45	56
Y ppm---	17	28	15	22	21	30	19	26	36	33	18.9	30	30	27	32
Zn ppm--	61	108	102	126	143	62	59	61	86	80	35	85	105	48	56

*These SiO_2 values are arithmetic means. If the element was below the detection limit for some samples, Cohen's technique was used to estimate the probable average.

†No siltstone category because only one sample was identified as a siltstone for this site.

¶Danforth Hills, N.W. Colorado; Corral Canyon, S.E. Central Wyoming; Henry Mountains and Emery, Utah.

Table 2.--Dispersion of data on bulk chemical composition of overburden rocks from two drill cores in the Capps coal field, Beluga coal area, south-central Alaska and other selected sites; also topsoils and mine spoil material from the San Juan Basin, N. Mex.

[Values are geometric deviations (except for some SiO_2 values). "Sand" indicates sandstone, "Silt" indicates siltstone, "Clay" indicates shale and other very fine-grained rocks, as used in the text; "n", number of samples analyzed where the San Juan Basin number of samples includes analytical duplicate splits of all the samples, the Ft. Union sandstones include 10 random analytical duplicate splits, the Ft. Union claystones include 12 random analytical duplicate splits, the Kimbeto site includes a total of 7 random analytical duplicate splits, and the other sites with Cretaceous overburden include a total of 35 random analytical duplicate splits; values for the Alaska suites do not include analytical duplicates; "n.d.", no data available; leaders (--), no dispersion]

Chemical Species	Alaska 1979 Core†		Alaska 1980 Core			Ft. Union overburden		Kimbeto, N. Mex.			Other sites with Cretaceous overburden¶			San Juan Basin	
	Sand n=7	Clay n=29	Sand n=9	Silt n=2	Clay n=11	Sand n=42	Clay n=50	Sand n=27	Silt n=4	Clay n=15	Sand n=110	Silt n=25	Clay n=77	Topsoil n=12	Mine spoil n=12
SiO_2%---	*7.8	*7.7	*3.6	*0.07	*5.1	1.1	1.1	*7.0	*5.1	*4.6	*12.1	*11.5	*10.4	1.1	1.1
Al_2O_3%--	1.5	1.1	1.1	1.0	1.2	1.2	1.2	1.4	1.1	1.1	1.6	1.3	1.3	1.5	1.1
CaO%----	1.5	1.3	1.2	1.1	1.2	1.2	3.2	3.8	2.2	1.9	8.6	3.9	3.8	1.3	1.2
Fe_2O_3%--	1.7	1.6	1.3	1.0	1.4	1.6	1.5	1.7	2.1	1.2	2.2	1.6	1.9	1.1	1.2
K_2O%----	1.5	1.2	1.1	1.0	1.1	1.2	1.2	1.3	1.5	1.3	1.5	1.2	1.5	1.1	1.1
MgO%----	1.4	1.4	1.2	1.2	1.3	2.0	1.6	1.7	1.8	1.2	3.9	1.8	1.8	1.1	1.1
Na_2O%---	1.4	1.4	1.1	--	1.8	1.6	1.8	1.7	1.2	1.2	2.8	2.5	3.0	1.0	1.2
TiO_2%---	1.5	1.2	1.2	1.1	1.3	1.2	1.2	1.5	1.6	1.1	1.7	1.2	1.3	1.1	1.1
P_2O_5%---	1.5	1.7	1.4	1.2	1.5	n.d.	n.d.	1.8	n.d.	1.9	n.d.	1.5	1.6	n.d.	n.d.
B ppm---	1.4	1.7	n.d.	n.d.	n.d.	1.5	1.3	1.4	1.2	1.4	1.6	1.4	1.6	1.8	1.5
Co ppm--	1.4	1.7	1.4	1.7	1.8	1.5	1.6	1.6	1.3	2.4	2.1	1.4	1.7	1.1	1.2
Cr ppm--	1.7	1.5	1.5	1.2	1.1	1.5	1.4	1.6	1.3	1.5	2.0	1.3	1.7	1.4	1.3
Cu ppm--	1.9	1.3	1.5	1.1	1.3	2.2	1.6	2.1	1.2	1.2	2.8	1.6	1.6	1.5	1.6
Mn ppm--	2.5	2.2	1.8	1.7	1.6	1.6	2.6	3.1	1.4	2.1	3.3	2.9	3.5	1.4	1.3
Mo ppm--	1.5	1.4	n.d.	n.d.	n.d.	1.6	1.6	1.4	1.3	1.3	1.5	1.4	1.6	1.3	1.1
Ni ppm--	1.4	1.5	1.5	1.2	1.3	1.6	1.7	1.7	1.1	1.9	2.3	1.4	1.6	1.1	1.2
Pb ppm--	1.3	1.4	1.2	--	1.2	1.7	1.7	1.5	1.7	1.6	1.7	1.5	1.6	1.2	1.3
V ppm---	1.4	1.4	1.3	1.3	1.1	1.5	1.5	1.8	1.2	1.3	2.1	1.2	1.4	1.1	1.3
Y ppm---	1.4	1.3	1.2	1.0	1.1	1.4	1.3	1.4	1.1	1.3	1.6	1.3	1.4	1.1	1.2
Zn ppm--	1.6	1.5	1.5	1.4	1.9	1.4	1.3	2.0	1.1	1.4	2.2	1.3	1.4	1.1	1.1

*These SiO_2 values are standard deviations.

†No siltstone category because only one sample was identified as a siltstone for this site.

¶Danforth Hills, N.W. Colorado; Corral Canyon, S.E. Central Wyoming; Henry Mountains and Emery, Utah.

For all samples of all suites, values for SiO_2, Al_2O_3, Fe (as Fe_2O_3), MgO, CaO, K_2O, TiO_2, and P_2O_5 were obtained by X-ray fluorescence spectrometry or, in some suites analyzed earlier or for particular species, by wet chemical methods of comparable accuracy. Thus, there should be little systematic error for the major elements. There has been, however, a gradual, modest improvement in accuracy during the years in which all of these suites of samples were analyzed. The Ft. Union suite was analyzed earliest, the Cretaceous and Kimbeto suites next, and the Alaska suites most recently.

Trace elements in samples from the 1980 Alaska core were determined by a different method from those used in all other suites. Although that new method may yield data of superior precision and accuracy, there may be a significant systematic (or random) offset between data derived by the two methods. The reader is again cautioned about this possible fundamental flaw in the body of data and the resulting problem in making comparisons (refer to the Analytical Procedures and Analytical Problems section of this report).

In table 1 only mean concentration values are given. For all chemical elements, except SiO_2, the type of mean used is the geometric mean rather than the arithmetic mean. The geometric mean tends to minimize the effect of the very high or very low values that may appear in the data set, and it tends to increase the likelihood that the mean value will fall in the range of the more common central values that are really most typical of the data set.

To give an idea of the dispersion (variance) of the data, a table of geometric deviations is presented in table 2; the rows and columns correspond to those of table 1. The geometric deviations provide information about whether the whole body of data is grouped about the mean, or broadly dispersed, with many values far from the mean. Geometric deviations are positive numbers. The farther they depart from unity, the greater the dispersion of the data about the mean. A geometric deviation of unity would mean that all of the data had the same value. The geometric means (GM) and geometric deviations (GD) are used in the following way to assess the spread of the data: about two-thirds of the values fall between a lower limit of GM/GD and an upper limit of GM·GD; about 95 percent of the values fall in the broader range defined by $GM/(GD)^2$ and $GM \cdot (GD)^2$. As an example of the use of geometric mean and geometric deviation data, zinc in claystone from "Other sites with Cretaceous overburden" (table 1) has a geometric mean of 105 ppm and a geometric deviation of 1.4; 95 percent of samples of such material should have values between $105/(1.4)^2 = 54$ ppm and $105 \cdot (1.4)^2 = 206$ ppm.

WHOLE-ROCK COMPOSITION OF SANDSTONES--MAJOR AND MINOR ELEMENTS

SiO_2--The 1979 Alaska core samples have large concentrations of SiO_2 (averaging 82 percent) relative to any suite of rocks presented in tables 1 and 2. Only the Cretaceous suite is close, with an average value of 79 percent. The 1980 Alaska samples have smaller concentrations (averaging 69 percent), similar to those from the Ft. Union and Kimbeto suites.

Al_2O_3--The concentrations in the 1979 Alaska samples (8 percent) and in the 1980 samples (15 percent) are close to the extreme high and low values for the set of other suites presented in the tables.

CaO--The 1979 and 1980 Alaska suites, at about 0.5 and 0.6 percent, respectively, have the lowest concentrations of any of the rock suites, except the Cretaceous suite which has a mean concentration intermediate between the two Alaska suites.

MgO--The 1979 and 1980 Alaska suites, at about 0.6 and 1 percent, respectively, are rather low, with the Ft. Union mean being twice as high as the higher (1980) Alaska suite and the lowest suite in the table, the Cretaceous suite, being equal to the 1979 Alaska suite.

Na_2O--The 1979 Alaska suite, which has a mean concentration of 1 percent, may be termed moderate or average for this environmentally important species, having about the same concentrations as the Paleocene Ft. Union formation suite. The 1980 Alaska suite has high concentrations (about 2 percent), about the same as those found in the suite from Kimbeto, N. Mex., of Cretaceous age. It should be pointed out here that the Cretaceous suite of tables 1 and 2 (which exclude the New Mexico samples) has a mean concentration that is around ten times smaller than that of the other suites.

K_2O--The 1979 Alaska core concentrations are about average (2 percent) relative to all suites of rocks presented, whereas those of the 1980 rocks are rather high (3 percent).

Fe_2O_3--As in the case of K_2O, above, the 1979 Alaska suite has concentrations that are about average (2 percent); those of the 1980 suite are rather high (3.5 percent).

TiO_2--The 1979 Alaska core mean of 0.3 percent is the lowest of all suites of rocks presented in the tables whereas the 1980 Alaska core mean of 0.6 percent is the highest of all the rock suites.

P_2O_5--The Alaska core concentrations of 0.1 percent correspond to the Kimbeto suite. There are no data available for the other suites.

WHOLE-ROCK COMPOSITION OF SANDSTONES--TRACE ELEMENTS

B--There are no individual or mean values for the 1980 Alaska core for this environmentally important element. The 1979 Alaska core mean of 17 ppm is about the same as those for Kimbeto, Cretaceous, and mine spoils. The mean of the Ft. Union suite is much larger, at 42 ppm.

Co--The means of the Alaska suites at 6 and 7 ppm may be larger than the Cretaceous suite mean of 4 ppm, perhaps slightly smaller than the mean for Kimbeto at 8 ppm. The Ft. Union suite mean of 11 ppm may be somewhat larger.

Cr--The means of the Alaska suites, at about 35 and 39 ppm, may be slightly smaller than that of the Ft. Union suite (46 ppm), but are about two times larger than means of the Cretaceous, Kimbeto, and mine spoils and topsoils suites.

Cu--The 1979 and 1980 Alaska suites, reported at 11 and 23 ppm, respectively, have higher concentrations than the Cretaceous suite, reported at 7 ppm. The concentrations of the Ft. Union and Kimbeto suites may be slightly larger than that of the 1979 Alaska core, at 14 ppm. Topsoils and mine spoils are reported at 10 and 18 ppm, respectively.

Mn--The Ft. Union suite (233 ppm) and the Kimbeto suite (183 ppm) both fall between the means for the two Alaska suites (167 and 412 ppm). The mean of the Cretaceous suite is much smaller (75 ppm), only half as large as the 1979 Alaska suite.

Mo--There are no individual or mean values for the 1980 Alaska core for this environmentally important element. The mean concentration for the 1979 core (2 ppm), analyzed by the same method as the other suites, is about the same as the values reported for those suites.

Ni--The means of the Alaska suites (23 and 24 ppm) are about the same as the mean for the Ft. Union suite (26 ppm). The Cretaceous suite and the Kimbeto suite both have much smaller means of 10 and 12 ppm, respectively.

Pb--The mean concentration for the 1979 Alaska samples (11 ppm) is about the same as the means for Ft. Union, Kimbeto, and the topsoils and mine spoils. The Cretaceous site might be smaller at 6 ppm. The reported mean value for the 1980 Alaska samples is about twice as high (22 ppm), for this difficult-to-analyze element.

V--The reported values for the 1979 and 1980 Alaska sample suites, at 60 and 71 ppm, respectively, are about the same as those for the Ft. Union and Kimbeto suites (at 75 and 60 ppm, respectively), slightly larger than those for the topsoils and mine spoils suites (45 and 56 ppm, respectively), and about two times larger than the value for the Cretaceous suite (37 ppm).

Y--The reported means for the 1979 and 1980 Alaska sample suites at 17 and 15 ppm, respectively, may be slightly smaller than the Cretaceous suite at 19 ppm and considerably smaller than the Kimbeto and Ft. Union suites at 26 and 30 ppm, respectively.

Zn--The reported values for the 1979 and 1980 Alaska suites are 61 and 102 ppm, respectively. The relatively undifferentiated Kimbeto suite coincides with the more differentiated of the two Alaska suites at 61 ppm. The Ft. Union suite, at 62 ppm, also coincides with the 1979 Alaska suite. The Cretaceous suite, at 35 ppm, has a concentration up to 2-3 times smaller than the Alaska suites.

WHOLE-ROCK COMPOSITION OF CLAYSTONES--MAJOR AND MINOR ELEMENTS

SiO_2--The average concentrations of the 1979 and 1980 Alaska sample suites, at 60 and 63 percent, respectively, are slightly larger than those of the Ft. Union and Cretaceous suites at 58 and 59 percent, and slightly smaller than that of the Kimbeto suite at 63 percent.

Al_2O_3--The Alaska suites, at 17 and 18 percent, are higher than the rock suites from other sites, except for the Ft. Union suite at 28 percent. The suites of topsoils and mine spoils have much smaller means, 5.5 and 11.5 percent, respectively.

CaO--The Alaska suites, at 0.7 and 0.6 percent, have smaller means than other rock suites. The Kimbeto suite is closest at 0.8 percent, the Cretaceous and Ft. Union suites higher at 1.4 and 1.7 percent. The suites of topsoils and mine spoils are still higher, at about 2 percent.

MgO--Means of the Alaska suites at 1.4 and 1.1 percent are like those of the Kimbeto and Cretaceous suites at 1.2 and 1.5 percent, respectively. The Ft. Union suite is higher at 2.3 percent. The suites of topsoils and mine spoils have smaller concentrations of 0.7 and 0.9 percent.

Na_2O-- Mean concentrations of the Alaska suites at 0.9 and 1 percent are similar to those of the Ft. Union and Kimbeto suites at 0.9 and 1.3 percent. The Cretaceous suite has much smaller concentrations, with a mean of 0.2 percent. Topsoils and mine spoils have considerably higher concentrations of 1.6 and 2.3 percent.

K_2O--The mean concentrations in the Alaska suites, at 2.5 and 2.6 percent, are similar to those of the other overburden suites, although the Cretaceous suite may be about 15 percent smaller. The topsoils and mine spoils are 1.8 and 1.7 percent, respectively.

Fe_2O_3--Each of the two Alaska suites, at 4.4 and 3.4 percent, nearly matches other suites: the Ft. Union suite is 4.3 percent, Kimbeto is 4.6 percent, and the Cretaceous suite is 3.3 percent.

TiO_2--The Alaska suites, at 0.7 percent, are close to the Ft. Union and Kimbeto suites, and perhaps slightly higher than the Cretaceous suite (0.6 percent).

P_2O_5--The Alaska suites, at 0.13 and 0.11 percent, lie between the Kimbeto (0.07 percent) and Cretaceous (0.14 percent) suites. There are no data available for the Ft. Union suite.

WHOLE-ROCK COMPOSITION OF CLAYSTONES--TRACE ELEMENTS

B--There are no individual or mean values for the 1980 Alaska core for this environmentally important element. The mean value of the 1979 Alaska suite, at 26 ppm, is slightly larger than that of the Kimbeto suite, at 19 ppm, and about the same as the value for the Cretaceous suite, at 28 ppm. However, the Ft. Union suite is about twice as high, at 59 ppm.

Co--Mean values for the 1979 and 1980 Alaska suites, at 9 and 8 ppm, respectively, correspond to values for the Ft. Union and Cretaceous suites, at about 9 ppm. The Kimbeto suite mean may be slightly larger at 12 ppm. Mine spoils and topsoils means are 9 and 6 ppm.

Cr--Mean values for the two Alaska suites are 61 and 70 ppm, about the same as the Ft. Union suite (72 ppm). The Kimbeto and Cretaceous suites have smaller means, at 30 and 43 ppm. Mine spoils and topsoils have still smaller means at 14 and 22 ppm.

Cu--The 1979 and 1980 Alaska suites, at mean values of 40 and 43 ppm, respectively, are about the same as the Ft. Union and Kimbeto suites, at 38 and 39 ppm, respectively. The Cretaceous suite may have a slightly smaller mean at 30 ppm. The topsoils and mine spoils have much smaller means, at 10 and 18 ppm.

Mn--The Alaska suites are the same as the Ft. Union suite, with a mean of about 300 ppm. The Cretaceous suite has about one-third less (210 ppm) and the Kimbeto suite has less than half as much (105 ppm).

Mo--There are no individual or mean values for the 1980 Alaska suite for this environmentally important species. The 1979 Alaska mean, at 2.3 ppm, is about the same as those of the Kimbeto suite at 2.8 ppm and the Cretaceous suite at 2.3 ppm (and close to the topsoils and mine spoils suites at 1.8 and 2.7 ppm). The Ft. Union suite has a much higher mean at 6.1 ppm, and it is in the region underlain by the Ft. Union formation (North Dakota) that problems of molybdenosis in ruminants are common.

Ni--Mean values for the 1979 and 1980 Alaska suites, at 36 and 38 ppm, may be larger than the Kimbeto (23 ppm), Cretaceous (27 ppm), and Ft. Union (30 ppm) suites. The mine spoils and topsoils suites have much lower means, at 12 and 9 ppm.

Pb--The Alaska suites, at 20 and 37 ppm, may be higher than the Ft. Union, Cretaceous, and Kimbeto suites at 11, 13, and 16 ppm, respectively, for this difficult-to-determine element. Values given for mine spoils and topsoils are 11 ppm.

V--Both Alaska suites, with reported mean values of about 120 ppm, have higher concentrations than the other overburden suites which have means around 90 ppm. Topsoils and mine spoils are 45 and 56 ppm, respectively.

Y--The 1979 and 1980 Alaska suites, at mean values of 28 and 21 ppm, are intermediate to the Ft. Union and Cretaceous suites, at 19 and 30 ppm, respectively. Mine spoils and topsoils have reported means of about 30 ppm.

Zn--The Alaska suites at about 110 and 140 ppm are similar to the Cretaceous suite at about 105 ppm. The means for the Ft. Union and Kimbeto suites are smaller at about 60 and 80 ppm, respectively. Means for topsoils and mine spoils are smaller yet, at 50 to 60 ppm.

DISCUSSION OF SOME INDIVIDUAL ALASKA SAMPLES

A few samples stand out as having overall higher or lower values for several chemical species and a few other samples have anomalously high or low values for a single chemical species. The Appendix presents complete element concentration data for all samples. Table 3 presents the ranges in whole rock concentrations of each element for both the 1979 and 1980 Alaska cores. Below, we discuss a number of the special samples, individually.

For some of the samples we discuss below, we analyzed duplicate splits. The results of these paired analyses indicate that there is in some cases poor precision for B, Ce, Cr, V, and Zn analyses and, to a lesser extent, for Ga, Mn, Ni, and Zr analyses of the 1979 Alaska core samples. No comparably poor precision was revealed by the results from the 1980 core, which was analyzed by a different method. The samples for which duplicate analyses were run have both field numbers listed at the beginning of the paragraph in the discussion below, and mention is made when discrepancies are apparent between the paired splits.

The 1979 Alaska core has several individual samples which have relatively high values for a variety of chemical species of environmental concern. Such samples do not appear to have any special spatial relationship to particular units of rock or coal in the column comprising the drill core. However, most of these samples are dark gray to black in color or contain a noticeable amount of coaly material. They are often massive (lack bedding or other structure). The majority of these samples were identified as claystones; those identified as other lithologic types also contain a large proportion of clay.

Table 3.--Range of bulk chemical composition of overburden rocks from two drill cores in the Capps coal field, Beluga coal area, south-central Alaska

["Sand" indicates sandstone, "Silt" indicates siltstone, "Clay" indicates shale and other very fine-grained rocks, as used in the text; "n", number of samples analyzed; "n.d.", no data available]

Chemical Species	Alaska 1979 Core			Alaska 1980 Core		
	Sand n=7	Silt n=1	Clay n=29	Sand n=9	Silt n=2	Clay n=11
SiO_2%---	71 - 90	63	42 - 70	64 - 75	65 - 65	54 - 76
Al_2O_3%--	4 - 13	15	13 - 20	12 - 18	16 - 17	12 - 23
CaO%----	.27 - .76	.73	.42 - 1.23	.51 - .81	.57 - .63	.46 - .72
Fe_2O_3%--	1.2 - 4.6	6.9	1.1 - 19.7	2.6 - 5.5	4.4 - 4.5	1.9 - 5.8
K_2O%----	1.0 - 3.2	2.3	1.5 - 3.1	2.7 - 3.2	2.6 - 2.7	1.9 - 3.3
MgO%----	.4 - 1.0	1.6	.4 - 1.9	.8 - 1.3	1.0 - 1.2	.6 - 1.6
Na_2O%---	.6 - 1.8	.8	.3 - 1.6	1.6 - 2.0	1.6 - 1.6	.2 - 1.5
TiO_2%---	.16 - .45	.84	.51 - .88	.43 - .74	.67 - .73	.31 - .80
P_2O_5%---	.07 - .20	.20	.07 - .50	.06 - .18	.11 - .14	.05 - .23
B ppm---	11 - 28	110	11 - 95	n.d.	n.d.	n.d.
Co ppm--	5.1 - 13.0	16.0	3.1 - 28.0	4.0 - 15.0	2.8 - 6.0	2.8 - 21.0
Cr ppm--	12 - 56	110	23 - 130	15 - 55	59 - 73	59 - 88
Cu ppm--	5 - 30	43	20 - 84	12 - 48	33 - 37	28 - 63
Mn ppm--	68 - 720	870	74 - 2400	230 - 1600	250 - 510	130 - 610
Mo ppm--	1.4 - 4.9	4.8	1.0 - 5.6	n.d.	n.d.	n.d.
Ni ppm--	18 - 36	84	16 - 97	12 - 43	26 - 33	27 - 74
Pb ppm--	6 - 15	18	11 - 60	20 - 30	30 - 30	30 - 50
V ppm---	42 - 110	190	76 - 210	43 - 98	86 - 120	100 - 140
Y ppm---	10 - 30	30	16 - 51	11 - 19	22 - 23	17 - 26
Zn ppm--	37 - 160	220	17 - 250	60 - 210	100 - 160	63 - 590

Claystones:

A010CTB2 and A01XCTB2 (11.9 meters)--This sample has high values for Ce, Cr and Ni, and fairly high values for Fe (as Fe_2O_3), Ba and Mo. Values for B, Mn, Nb, V, and Zn may be fairly high although there is discrepancy between analytical duplicates, and the lower values are within the normal range. The sample is a medium-dark-gray, massive, soft, slightly silty claystone with some organic fragments.

A140CA14 (32.6 meters)--This sample has large concentrations of Co, Cr, Cu, Ga, Mo, and Ni, and above average concentrations of K_2O, B, Ba, Pb, Sc, and V. Concentrations of TiO_2 and Yb are rather small. It is a black, massive, pure claystone with coarse coaly flakes. Because of the appearance of the sample, we believe that there may be contamination by drilling mud.

A150CMA8 (33.6 meters)--This sample has relatively high values of Cr and Y, and larger than average values of Ba, Be, Ce, Nb, Ni, and V, relative to other samples. It is a dark-gray silty and sandy claystone with mica flecks and organic splotches.

A210CA43 (42.3 meters)--This sample contains a very large amount of Mn, large amounts of CaO, Fe (as Fe_2O_3) and P_2O_5, larger than average amounts of Be and Co. Concentations of TiO_2, Ba and Sr are small, and concentrations of SiO_2, Cr, La, Nb, and Zr are smaller than average. It is a medium-dark-gray, well-bedded, pure claystone with elongate coaly fragments.

A240CA14 and A24XCA14 (45.4 meters)--This sample may have fairly high values for B, Ce, Cr, Cu, Mn, Ni, and V, although there is considerable discrepancy between the analytical duplicates. It is a black, moderately well-bedded, pure claystone with tiny plant fragments.

A340CT23 (115.3 meters)--This sample has large concentrations of CaO, Be, Pb, and Sr, an above average concentration of V, a very small concentration of Zn, small concentrations of Fe (as Fe_2O_3), K_2O, MgO, and SiO_2, and fairly small concentrations of Al_2O_3, TiO_2, Co, Mn, and Ni. It is a grayish-black, coaly, brittle, silty claystone with fine mica flecks.

A380CTB2 (118.0 meters)--This sample is very high in Zn, relatively high in Ba, Ga, Mo, Pb and Y, fairly high in TiO_2, B, Cr, Cu, Ni, Sc, and V, and low in Na. It is a medium-dark-gray, brittle, slightly silty claystone with coaly fragments.

Sandstone:

A180SCF9 and A18XSCF9 (38.4 meters)--This sample is high in Mn, Mo and Na. It is a salt and pepper sandstone with a clayey matrix.

Siltstone:

A060TC42 and A06XTC42 (17.6 meters)--This sample contains large amounts of Mn and Mo. Values for B, Cr, Ni, and Zn may be fairly high although this is not borne out by the analytical duplicate. It is a medium-dark-gray, slightly clayey siltstone with visible root hairs and mica flecks.

Coal

A370CB14 (116.4 meters)--This sample has a high CaO content and is low to very low in almost all other chemical species. It was taken between two members of the Waterfall Coal Beds and is black, well-bedded and vitreous.

The individual anomalous values for the less differentiated 1980 Alaska core are generally less extreme than those for the 1979 core. The samples that stand out in the 1980 suite have only somewhat higher or lower values for a variety of chemical species. There are a few samples that have noticeably higher or lower values for a single chemical species. Only one sample stands out as having relatively high values for a variety of chemical species of environmental concern and it (C140XX14) is largely lignitic. The other, less extreme samples are mostly claystones, but, as in the other Alaska suite, those samples identified as other lithologic types also contain a large proportion of clay, and generally contain coaly material.

Claystones:

C020CAA2 (4.7 meters)--This sample contains large amounts of SiO_2, Co and Zn, and fairly large amounts of K_2O and CaO. There are small amounts of Fe (as Fe_2O_3) and P_2O_5, and fairly small amounts of Al_2O_3 and MgO. The sample is a light-olive-gray pure claystone and may contain some coaly debris. Contamination by drilling mud is possible.

C050CTB9 (9.2 meters)--This sample has very high Zn and relatively high Fe (as Fe_2O_3), Co and Mn values. It is a yellowish-brown silty claystone. Drilling mud contamination is possible.

C110CA62 and C11XCA62 (18.9 meters)--This sample has fairly high values for Fe (as Fe_2O_3), Cr, Cu, Ni, and Pb. It is a medium-light-gray, moderately well bedded, nearly silt free claystone with coal stringers.

C12OCT34 and C12XCT34 (24.2 meters)--This sample has a very high Sr concentration and fairly high concentrations of Al_2O_3, P_2O_5 and Li. There are low Co, Mn, Na, and Zn concentrations and fairly low K_2O, SiO_2, Fe (as Fe_2O_3), and Ni concentrations. This sample was taken between two members of the Waterfall Coal Beds and is a dark-gray, slightly silty claystone with distinct but wavy bedding and coal stringers.

C13OCT62 (28.7 meters)--This sample contains a relatively large amount of Ni, a fairly large amount of TiO_2, and a fairly small amount of CaO. It was taken between two members of the Waterfall Coal Beds and is a medium-light-gray, moderately well bedded, silty claystone with fibrous plant fragments.

Sandstones:

C03OSCB7 and C03XSCB7 (5.2 meters)--This sample has a very high Mn value with fairly high Fe (as Fe_2O_3) and Zn values and a fairly low CaO value. It is a moderate-yellowish—brown, clayey fine sandstone. Drilling mud contamination is possible.

C18OSC67 (39.4 meters)--This sample contains a fairly large amount of Co and Ni and a fairly small amount of Fe (as Fe_2O_3). It is a light-gray, massive, clayey fine sandstone with a medium-dark-gray clay-rich layer and some coaly streaks.

Coal:

C14OXX14 and C14XXX14 (31.6 meters)--This sample has large concentrations of Cr, Cu, V, and Zn, and fairly large concentrations of CaO, Co and Ni. Values for P_2O_5, SiO_2 and Na are small. This sample was taken from the bottom member of the Waterfall Coal Beds and is largely lignite, black and well bedded.

DISCUSSION AND CONCLUSIONS

Success of differentiation by lithologic type in hand specimen name assignment--As can be seen in figure 4, there is relatively little overlap in SiO_2 concentration of sandstones and claystones for the Alaska cores. Hand specimen inspection is a reasonably reliable way of assigning names denoting the lithologic type of rocks in these suites, even though one suite (1979 core) is much more differentiated than the other.

Elements of interest in reclamation considerations--Elements of widely cited environmental importance for coal area reclamation in the United States are Na, B and Mo. Other elements receiving attention in environmental discussions are Co, Cr, Cu, Ni, Pb, V, Y and Zn; we consider these latter to be of less practical relevance in reclamation considerations than Na, Mo and B for the types of sedimentary rock systems which contain coal in the Western United States. We believe that they are so commonly cited in environmental discussions as potential toxins (or, in the case of nutritious elements such as Cu and Zn, as being deficient) largely for two reasons. The first is because much is known about their physiological effects on plants and animals. The second is that there have been citations in the biogeochemical literature of anomalously high concentrations of many of these elements in very specialized and generally uncommon geologic settings, such as in intensively studied regions of outcrop of highly ferromagnesian igneous and metamorphic rocks in England and Scotland.

Differences in contents of key elements by lithologic type--For the elements we consider to be of greatest environmental concern, Na, Mo and B, the concentration relations between the coarse- and fine-grained lithologic types in the two Alaska suites is about the same as in most suites from other areas. There is a somewhat larger amount of Na in the sandstones than in the claystones, but more Mo and B in the claystones. In some other suites the segregation is stronger between rock types, but the sense is the same. (Mo is more strongly segregated into the fine-grained rock type in the Ft. Union suite.) As for the other elements commonly cited as of environmental interest, Co, Cr, Cu, Ni, Pb, V, Y and Zn, the concentrations are generally larger in the fine-grained rocks in both the Alaska rock suites and in the suites from other sites. As would be anticipated, the typical differences for these elements between coarse- and fine-grained rocks are less pronounced in the less strongly lithologically differentiated suites (Kimbeto, N. Mex. and the 1980 Alaska suite), and more pronounced in the more strongly differentiated suites.

Magnitude of concentrations of key elements in rocks of the Alaska suites compared to rock suites from other sites--The concentration of B in the Alaska rocks is similar to that in most other suites, except for the Ft. Union suite which is much larger. The concentration of Na in Alaska rocks is comparable to those of other suites except that of the Cretaceous suite which is much smaller. Concentrations of Mo in the Alaska rocks are similar to those of other suites except that the Ft. Union suite fine-grained rocks have much larger Mo concentrations.

For the other elements commonly cited as of environmental interest, Co, Cr, Cu, Ni, Pb, V and Zn, the following comparisons can be made: the mean concentration values of Co and Cr in fine- or coarse-grained Alaska rocks are not larger than the largest mean value in other suites; Ni and V in fine-grained Alaska rocks have the largest mean values of other rock suites; Cu, Pb and Zn in both fine- and coarse-grained Alaska rocks have the largest mean values among other rock suites.

Additional chemical considerations from kinds of data not presented in this report--Chemical elements are released from disturbed spoil material after mining, during time periods of varying lengths. The whole-rock chemical composition of overburden material can give only the most general indications of the nature and magnitude of these processes. More specific predictive power can come from a combination of the whole-rock composition data presented in this study with information in the following three areas:

1. The identity and abundance of the mineral species in the rock, especially clay minerals, carbonate, sulfide, and Fe and Mn oxide and oxyhydroxide species.

2. The amount of "available" or leachable chemical species which can be removed from the rock by various solution leach treatments. A variety of such treatments, intended to simulate different natural effects, have been developed by numerous workers over a period of several decades. These are intended to simulate the actions of natural waters or plant roots on the rocks.

3. A knowledge of the temperature, moisture and vegetation regimes of the weathering environment to which the disturbed rock material will be exposed.

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APPENDIX

Data grouped by main lithologic type for each Alaska core.

The sample code is explained in the following way:

Column 1--Core code.

A = 1979 Alaska core

C = 1980 Alaska core

Columns 2 and 3--Depth code.

Increasing numbers denote increasing depth (the actual depth values can be obtained from the authors).

Column 4--Analytical duplicate code.

0 = original sample

X = random analytical duplicate split

Column 5--Main lithologic type code.

C = claystone (shale and other very fine grained rocks)

S = sandstone (grain size greater than 0.2 mm, approximately)

T = siltstone (grain size visible by hand lens, 0.2 mm or smaller)

Column 6--Lithologic type modifier code.

A = pure

C = clayey

S = sandy

T = silty

M = mixed (silty and sandy)

B or XX = coal

Column 7--Color code (based on the Rock Color Chart distributed by the National Research Council, Washington, D.C.).

(The actual color index code can be obtained from the authors.)

Column 8--Facies index code (developed by A. Chleborad).

The chemical species column index code is explained in the following way:

x = Analyzed by X-ray fluorescence spectrometry or by alternate methods of comparable accuracy.

S = Analyzed by semiquantitative spectrographic methods.

Capps Coal Field 1979 Core

Sample	Depth-m	LOI %	Al2O3%-x	CaO%-x	Fe2O3%-x	K2O%-x	MgO%-x	P2O5%-x	SiO2%-x	TiO2%-x	B ppm-S	Ba ppm-S
						Claystone						
A010CTB2	11.9	9.5	16	.75	8.1	2.5	1.8	.20	59	.80	95	1,200
A01XCTB2	11.9	9.5	16	.74	8.0	2.5	1.8	.20	59	.80	36	1,100
A020CA42	12.4	12.2	18	.86	9.8	2.6	1.9	.20	53	.74	35	1,100
A030CA33	15.4	28.5	15	.90	3.1	1.9	1.2	<.10	47	.66	17	730
A03XCA33	15.4	28.0	16	.92	3.2	1.9	1.3	<.10	47	.67	16	770
A040CT34	16.0	14.0	19	.81	4.7	2.8	1.9	.30	55	.75	20	1,200
A04XCT34	16.0	16.0	19	.85	4.4	2.7	1.8	.30	53	.74	28	1,500
A050CT33	16.1	11.6	19	.58	5.6	2.7	1.8	<.10	57	.75	33	1,000
A070CA34	16.6	13.3	20	.55	3.5	2.7	1.9	<.10	56	.82	39	1,100
A080CM08	25.5	6.8	16	.71	4.2	2.5	1.4	.20	65	.73	18	1,000
A090CMB7	26.7	5.3	14	.74	4.1	2.9	1.1	.10	70	.54	12	960
A09XCMB7	26.7	5.1	14	.74	4.1	2.8	1.1	.10	69	.54	15	1,100
A100CTB5	27.3	7.6	16	.75	4.9	2.4	1.3	.20	63	.75	16	820
A110CA52	28.1	6.6	17	.65	4.4	2.6	1.7	.20	64	.73	23	1,000
A120CT49	28.9	6.6	16	.74	5.2	2.6	1.5	.20	64	.75	18	1,000
A140CA14	32.6	18.4	19	.88	5.0	3.1	1.9	.10	50	.52	69	1,200
A150CMA8	33.6	6.8	16	.66	5.5	2.5	1.6	.20	65	.76	66	1,300
A160CM47	34.1	5.5	15	.60	4.1	2.7	1.3	.10	67	.63	16	1,000
A170CM47	35.8	5.2	15	.63	4.3	2.6	1.4	.20	68	.71	25	1,200
A190CA52	39.2	7.0	16	.78	6.7	2.5	1.7	.30	62	.73	22	750
A200CMF7	40.5	5.0	13	.60	4.8	2.8	1.1	.10	69	.51	12	840
A210CA43	42.3	17.5	14	1.23	19.7	2.0	1.5	.50	42	.54	21	590
A220CA24	42.5	22.2	18	.97	4.4	2.7	1.7	.20	48	.64	22	1,100
A230CAC2	43.4	9.8	19	.46	4.1	2.5	1.4	<.10	61	.80	28	960
A23XCAC2	43.4	10.2	19	.46	3.9	2.5	1.4	<.10	61	.81	26	1,100
A240CA14	45.4	11.9	18	.69	4.9	2.6	1.7	.20	58	.75	35	1,100
A24XCA14	45.4	12.6	18	.72	4.9	2.6	1.7	.20	57	.77	63	1,300
A250CTH8	46.0	6.2	16	.55	3.2	2.8	1.2	.10	68	.70	38	1,200
A260CAA3	54.6	10.3	18	.42	2.3	2.1	1.3	<.10	63	.88	42	990
A270CMC7	56.5	6.2	16	.47	2.8	2.4	1.3	<.10	69	.81	18	770
A280CB36	61.8	6.6	15	.71	3.4	2.3	1.5	.10	68	.81	29	840
A340CT23	115.3	33.2	13	1.23	1.1	1.5	.4	<.10	48	.58	22	890
A350CTB2	115.4	7.8	17	.76	3.2	2.5	1.1	<.10	64	.75	13	1,000
A360CM53	115.8	7.6	17	.75	3.9	2.6	1.1	.10	64	.71	11	620
A380CTB2	116.0	7.6	20	.56	4.0	2.6	1.4	.10	62	.84	59	1,400
						Sandstone						
A130SCE7	29.9	3.5	13	.76	3.5	3.3	.9	.10	71	.38	16	980
A180SCF9	38.4	4.5	12	.67	4.6	2.9	1.0	.10	72	.45	22	1,200
A18XSCF9	38.4	4.0	12	.63	4.0	2.9	.9	.10	72	.41	35	1,300
A290SCF7	62.0	2.9	8	.49	1.6	2.1	.6	<.10	82	.29	16	940
A300SCE9	67.5	2.1	9	.49	1.6	2.2	.7	<.10	81	.32	11	1,100
A310SCD9	106.0	1.5	6	.30	1.3	1.6	.5	<.10	88	.19	20	1,100
A31XSCE0	106.0	1.8	6	.29	1.2	1.5	.5	<.10	87	.18	19	1,100
A320SCD0	107.7	2.8	5	.50	1.6	1.2	.5	.20	87	.17	28	720
A330SCD0	109.2	1.7	4	.27	1.2	1.0	.4	<.10	90	.16	14	790
A33XSCD0	109.2	1.6	4	.20	1.0	.9	.4	<.10	90	.13	22	990
						Siltstone						
A060TC42	17.6	8.3	15	.73	6.9	2.3	1.6	.20	63	.84	110	1,300
A06XTC42	17.6	8.3	15	.72	6.8	2.3	1.6	.20	63	.83	31	900
						Coal						
A370CB14	116.4	51.7	12	1.30	2.2	1.6	.7	<.10	28	.33	15	450

Sample	Be ppm-S	Ce ppm-S	Co ppm-S	Cr ppm-S	Cu ppm-S	Ga ppm-S	Ge ppm-S	La ppm-S	Mn ppm-S	Mo ppm-S	Na%-S
					Claystone						
A010CTB2	2.4	120	12.0	130	44	23	<2.2	49	1,000	4.1	.87
A01XCTB2	2.1	77	14.0	83	49	14	1.5	31	580	4.3	.58
A020CA42	1.5	54	12.0	62	41	15	1.0	24	440	1.9	.45
A030CA33	<1.0	<46	4.6	31	29	8	<1.0	18	76	1.0	.50
A03XCA33	<1.0	54	6.1	48	29	9	1.0	26	100	1.3	.52
A040CT34	1.4	70	5.4	41	39	13	1.7	31	200	1.9	.46
A04XCT34	1.6	<46	7.1	62	51	12	<1.0	27	130	2.2	.49
A050CT33	1.7	<46	9.9	59	40	13	1.1	23	240	2.1	.58
A070CA34	1.7	<46	5.4	79	39	15	1.4	26	110	1.7	.38
A080CMB8	2.2	69	8.2	70	50	14	1.6	35	400	2.4	.58
A090CMB7	1.8	<46	6.9	40	28	11	1.1	28	320	1.8	.61
A09XCMB7	2.2	53	7.5	37	37	13	1.7	29	360	2.2	.61
A100CTB8	1.9	61	6.9	59	48	14	<1.0	29	660	2.6	1.20
A110CA52	1.9	63	18.0	74	40	15	1.4	29	400	2.3	.51
A120CT48	2.1	<46	10.0	73	39	15	1.7	31	540	2.6	.55
A140CA14	2.3	82	28.0	110	84	36	<2.2	34	420	5.6	.75
A150CMA6	2.5	92	12.0	120	43	21	<2.2	39	780	2.7	.95
A160CM47	1.8	52	9.0	66	28	13	1.5	23	350	2.1	.57
A170CM47	2.3	62	22.0	65	38	15	1.7	34	360	2.8	.58
A190CAB2	1.6	<46	7.7	43	39	10	1.2	22	690	3.2	1.10
A200CMF7	2.0	57	8.4	40	29	10	<1.0	28	470	2.2	.68
A210CA43	2.7	<46	22.0	23	39	12	<1.0	18	2,400	2.5	.76
A220CA24	1.1	<46	5.4	42	51	13	<1.0	15	180	1.7	.58
A230CAC2	1.7	57	6.6	73	37	18	1.3	28	230	2.3	.76
A23XCAC2	1.8	49	6.6	74	36	13	1.2	28	260	2.3	.69
A240CA14	2.0	58	19.0	63	52	17	1.3	32	360	2.8	.82
A24XCA14	2.1	120	24.0	120	81	29	<2.2	49	670	2.8	.70
A250CTB8	1.7	47	7.1	64	53	15	1.9	29	210	2.3	.58
A260CA43	1.4	<46	4.2	69	20	11	1.4	27	74	1.5	.22
A270CMC7	1.5	<46	8.5	43	27	9	1.0	22	92	1.3	.68
A280CM38	2.0	60	8.4	79	36	11	1.3	34	120	2.1	.87
A340CT23	3.5	52	3.1	77	45	19	<2.2	23	94	1.4	.91
A350CTB2	1.6	72	6.5	51	47	15	1.6	36	240	1.8	1.10
A360CMB8	1.9	60	7.5	44	36	14	1.1	32	320	2.6	.52
A380CTB2	2.3	100	10.0	110	63	38	<2.2	47	440	4.7	.43
					Sandstone						
A130SCE7	1.7	<46	6.4	30	21	9	1.1	20	350	1.5	.79
A180SCF9	1.6	75	13.0	53	30	19	<2.2	22	720	4.9	1.30
A18XSCF7	1.8	69	13.0	55	29	20	<2.2	25	650	3.5	1.50
A290SCF9	2.5	<46	5.3	56	5	4	1.4	14	82	2.1	1.00
A300SCC9	2.0	<46	5.2	34	6	4	1.3	16	86	1.8	1.00
A310SCD0	2.5	<46	6.0	39	11	3	1.7	16	110	1.9	.75
A31XSCD0	2.0	<46	4.6	19	11	3	1.3	10	110	2.2	.65
A320SCD0	1.1	<46	9.7	47	12	5	<2.2	9	270	1.4	.59
A330SCD0	1.6	<46	5.1	12	8	<2	1.6	7	68	2.0	.48
A33XSCD0	2.2	<46	5.3	13	7	2	1.6	7	80	2.3	.48
					Siltstone						
A060TC42	2.5	100	16.0	110	43	22	<2.2	27	870	4.8	.63
A06XTC42	1.7	76	9.2	66	37	10	1.4	35	650	3.1	.08
					Coal						
A370CB14	<1.0	<46	6.8	19	41	5	<1.0	13	59	3.1	.25

Capps Coal Field 1979 Core (continued)

Sample	Nb ppm-S	Ni ppm-S	Pb ppm-S	Sc ppm-S	Sr ppm-S	V ppm-S	Y ppm-S	Yb ppm-S	Zn ppm-S	Zr ppm-S
Claystone										
A010CTB2	24	65	20	24	180	200	41	1.9	130	280
A01xCT32	14	54	20	14	110	120	25	2.9	170	160
A020CA42	8	40	18	12	91	120	25	2.4	100	110
A030CA33	8	18	11	9	68	80	18	2.2	94	110
A03xCA33	10	21	11	12	120	89	22	2.5	85	140
A040CT34	17	27	18	13	120	100	35	3.2	92	240
A04xCT34	14	32	20	14	120	130	26	3.0	190	270
A050CT33	11	38	17	15	100	130	23	2.6	120	150
A070CA34	12	30	19	12	110	130	18	2.3	130	110
A080CM68	13	30	20	16	130	120	33	3.2	83	200
A090CMB7	7	25	17	11	130	80	23	2.4	96	140
A09xCMU7	12	26	17	12	150	92	32	2.7	120	170
A100CTB8	13	26	19	13	120	91	29	3.1	100	230
A110CA52	14	54	22	14	110	130	33	3.0	130	230
A120CT48	13	32	21	15	140	110	32	3.4	110	230
A140CA14	12	97	37	25	150	200	38	1.6	130	190
A150CMA8	22	59	21	23	170	210	49	2.6	140	280
A160CM47	11	30	17	11	120	91	23	2.5	93	160
A170CM47	15	48	19	13	120	120	35	3.2	110	250
A190CAB2	13	34	17	12	93	110	27	2.4	99	270
A200CMF7	9	26	15	11	120	76	23	2.7	83	140
A210CA43	6	55	19	10	71	76	27	2.3	87	89
A220CA24	7	22	17	11	140	100	16	2.1	110	120
A230CAC2	12	31	21	14	120	130	29	3.0	96	160
A23xCAC2	16	30	20	15	130	130	31	2.9	92	190
A240CA14	13	77	20	14	130	150	34	3.5	150	220
A24xCA14	14	120	26	26	180	210	43	2.8	170	190
A250CTB8	11	34	22	15	110	140	28	2.9	170	160
A260CAA3	19	35	15	14	100	140	22	2.3	120	250
A270CMC7	13	33	15	10	77	82	17	1.5	150	110
A280CM38	15	36	16	14	130	130	26	2.6	130	220
A340CT23	15	16	60	20	270	180	34	1.6	17	250
A350CTB2	17	33	19	14	160	95	30	3.0	100	240
A360CM68	15	28	18	13	150	92	30	3.1	130	250
A380CTB2	21	74	41	28	150	210	51	2.1	250	260
Sandstone										
A130SCE7	11	18	14	8	140	63	19	1.9	64	120
A180SCF9	13	36	15	15	170	110	30	1.7	66	130
A18xSCF7	12	44	18	15	190	110	31	1.9	82	160
A290SCF9	6	20	11	6	120	46	16	1.4	40	54
A300SCC9	8	19	11	6	120	62	21	1.5	45	78
A310SCD0	7	20	11	4	110	48	15	1.0	37	53
A31xSCD0	6	14	9	3	80	54	13	1.0	33	70
A320SCD0	10	36	7	5	96	73	15	.6	69	64
A330SCD0	5	19	8	3	59	42	10	.7	160	54
A33xSCD0	6	18	9	2	64	49	11	.8	160	64
Siltstone										
A060TC42	19	84	18	21	120	190	30	1.8	220	190
A06xTC42	12	36	16	14	120	120	32	3.3	67	240
Coal										
A370CB14	<5	13	13	9	120	73	20	2.2	52	100

Capps Coal Field 1980 Core

Sample	Depth-m	LOI %	Al2O3%-x	CaO%-x	Fe2O3%-x	K2O%-x	MgO%-x	P2O5%-x	SiO2%-x	TiO2%-x
Claystone										
C010CT42	3.6	9.0	18	.61	3.8	2.5	1.1	.12	62	.74
C020CAA2	4.7	2.2	13	.72	1.9	3.3	.6	.05	76	.31
C050CTB9	9.2	6.4	17	.53	5.8	2.6	1.2	.17	64	.70
C070CT38	12.4	8.6	18	.69	3.8	2.5	1.2	.14	62	.77
C090CT32	15.9	7.9	19	.66	3.8	2.5	1.3	.11	63	.71
C09XCT32	15.9	8.3	18	.66	3.7	2.5	1.2	.11	63	.70
C100CT33	16.6	8.9	18	.59	4.2	2.6	1.4	.15	62	.71
C110CA62	18.9	6.9	20	.56	4.6	2.9	1.6	.14	61	.76
C11XCA62	18.9	6.9	20	.57	4.6	2.9	1.6	.14	61	.75
C120CT34	24.2	16.3	23	.48	2.0	1.9	.9	.23	54	.69
C12XCT34	24.2	17.2	23	.49	2.0	1.9	.9	.22	54	.68
C130CT62	28.7	7.7	18	.46	3.3	2.6	1.2	.10	65	.80
C150CT48	33.4	8.8	18	.55	3.4	2.6	1.3	.08	63	.73
C210CT68	45.4	7.6	18	.63	3.1	2.4	1.1	.07	65	.77
Sandstone										
C030SCB7	5.2	5.7	17	.52	5.5	2.7	1.0	.14	65	.69
C03XSCB7	5.2	5.8	17	.52	5.5	2.7	1.0	.14	65	.71
C080SC57	13.8	6.2	16	.72	4.2	2.8	1.0	.12	66	.67
C160SC67	34.0	6.7	15	.60	2.9	2.8	1.0	.13	68	.63
C16XSC67	34.0	5.3	15	.55	2.9	2.9	1.0	.11	69	.62
C170SC67	36.2	5.2	15	.81	4.7	2.8	1.1	.18	68	.59
C17XSC67	36.2	5.5	15	.79	4.7	2.8	1.2	.18	67	.61
C180SC67	39.4	4.0	15	.60	2.9	3.0	1.0	.09	70	.58
C190SC49	40.6	3.7	14	.68	2.6	3.2	.8	.07	73	.43
C19XSC49	40.6	3.9	14	.71	2.8	3.3	.9	.07	71	.45
C200SC49	43.5	4.8	15	.61	3.4	3.0	.9	.09	69	.56
C220SC59	48.4	6.3	18	.51	3.9	2.7	1.3	.15	64	.74
C22XSC59	48.4	1.7	12	.72	1.7	3.3	.6	<.05	77	.29
C230SC59	48.7	2.5	12	.70	2.7	3.1	.8	.06	75	.46
Siltstone										
C040TC47	7.2	7.2	16	.57	4.4	2.7	1.0	.11	65	.67
C060TC48	11.3	5.9	17	.63	4.5	2.6	1.2	.14	65	.73
C06XTC48	11.3	5.9	17	.63	4.3	2.6	1.3	.13	65	.74
Coal										
C140XX14	31.6	24.4	19	.77	3.5	2.5	1.4	<.05	48	.60
C14XXX14	31.6	24.2	19	.78	3.5	2.5	1.4	<.05	48	.62

Capps Coal Field 1980 Core (continued)

Sample	Ba ppm-S	Ce ppm-S	Co ppm-S	Cr ppm-S	Cu ppm-S	La ppm-S	Li ppm-S	Mn ppm-S	Na%-S
				Claystone					
C010CT42	830	50	5.0	64	53	28	52	200	1.0
C020CAA2	850	60	21.0	72	34	29	52	350	1.0
C050CTB9	810	50	17.0	62	37	25	48	610	1.1
C070CT38	790	60	8.0	70	45	31	57	420	1.1
C090CT32	860	50	8.0	59	28	25	53	380	1.0
C09XCT32	820	50	8.0	57	29	24	51	360	1.0
C100CT33	870	50	6.0	75	37	25	55	390	.9
C110CA62	900	60	6.0	88	63	28	65	440	.7
C11XCA62	900	60	6.0	83	63	29	65	430	.7
C120CT34	970	50	<4.0	80	42	26	76	130	.1
C12XCT34	970	50	<4.0	78	42	26	75	130	.1
C130CT62	810	60	7.0	78	49	30	51	250	.7
C150CT48	810	50	6.0	64	49	26	50	240	.8
C210CT68	690	50	11.0	66	43	28	52	220	1.1
				Sandstone					
C030SCB7	810	60	6.0	55	48	24	46	1,600	1.2
C03XSCB7	810	60	6.0	35	46	24	46	1,600	1.1
C080SC57	800	50	6.0	55	27	27	49	540	1.3
C160SC67	840	50	4.0	51	31	23	40	260	1.2
C16XSC67	850	40	4.0	44	29	24	41	260	1.2
C170SC67	810	40	5.0	49	27	22	39	580	1.3
C17XSC67	820	40	5.0	51	29	23	42	560	1.2
C180SC67	820	40	15.0	47	23	22	43	280	1.3
C190SC49	820	30	7.0	32	22	16	36	280	1.4
C19XSC49	830	30	7.0	210	24	16	37	300	1.4
C200SC49	860	40	6.0	49	16	22	42	390	1.3
C220SC59	840	20	5.0	15	12	13	28	230	1.5
C22XSC59	810	20	4.0	22	10	14	27	210	1.5
C230SC59	770	30	6.0	27	15	18	31	370	1.3
				Siltstone					
C040TC47	760	50	<4.0	59	33	26	44	250	1.2
C060TC48	840	50	6.0	73	37	28	50	510	1.2
C06XTC48	830	50	8.0	71	38	29	50	490	1.2
				Coal					
C140XX14	910	40	16.0	92	71	22	52	230	.2
C14XXX14	930	40	17.0	91	72	23	54	230	.2

Capps Coal Field 1980 Core (continued)

Sample	Nd ppm-S	Ni ppm-S	Pb ppm-S	Sc ppm-S	Sr ppm-S	V ppm-S	Y ppm-S	Zn ppm-S
				Claystone				
C010CT42	30	43	30	20	130	110	24	150
C020CAA2	30	34	40	19	120	130	22	330
C050CTB9	30	36	40	18	120	110	21	590
C070CT38	30	31	30	19	140	110	25	130
C090CT32	30	35	30	19	150	100	21	100
C09XCT32	20	35	40	18	140	96	20	99
C100CT33	30	37	40	19	130	120	19	98
C110CA62	40	56	50	23	120	140	26	140
C11XCA62	30	55	40	22	120	140	27	140
C120CT34	30	27	40	22	330	140	23	63
C12XCT34	20	29	40	21	330	140	23	60
C130CT62	30	74	30	18	100	120	19	120
C150CT48	20	31	40	19	110	110	17	120
C210CT68	30	35	40	17	140	100	19	110
				Sandstone				
C030SCB7	30	30	30	18	120	98	19	210
C03XSCB7	20	31	30	18	120	100	19	200
C080SC57	30	27	30	14	150	82	18	160
C160SC67	30	28	20	15	140	91	17	110
C16XSC67	20	25	30	15	130	89	17	100
C170SC67	30	28	20	15	150	86	19	98
C17XSC67	20	33	20	16	150	95	20	110
C180SC67	10	43	20	13	140	79	17	100
C190SC49	20	22	20	9	170	57	12	87
C19XSC49	10	29	20	10	170	60	13	90
C200SC49	20	23	20	12	140	72	16	96
C220SC59	10	12	20	<8	180	43	11	60
C22XSC59	<10	11	20	8	180	41	11	56
C230SC59	10	15	20	9	170	55	12	64
				Siltstone				
C040TC47	20	26	30	16	130	86	23	100
C060TC48	30	33	30	19	140	120	22	160
C06XTC48	30	33	40	19	140	120	22	160
				Coal				
C140XX14	20	50	40	21	110	160	18	260
C14XXX14	20	48	40	22	120	160	20	240