

THE GEOLOGICAL SURVEY OF WYOMING
Daniel N. Miller, Jr., State Geologist

REPORT OF INVESTIGATIONS No. 16

COAL ANALYSES AND LITHOLOGIC DESCRIPTIONS
OF FIVE CORE HOLES DRILLED IN THE CARBON BASIN
OF SOUTHCENTRAL WYOMING

By
Gary B. Glass



*Research sponsored by the U.S. Geological Survey,
Department of the Interior, under
Grant Number 14-08-0001-G-193.*

LARAMIE, WYOMING

1978

First printing of 1,000 copies, September, 1978,
by Pioneer Printing and Stationery Company, Inc.,
Cheyenne

For sale by The Geological Survey of Wyoming. Write

The Geological Survey of Wyoming
P.O. Box 3008, University Station
Laramie, Wyoming 82071

or visit the Geological Survey Building, in Laramie.

Copyright The Geological Survey of Wyoming, 1978

THE GEOLOGICAL SURVEY OF WYOMING
Daniel N. Miller, Jr., State Geologist

REPORT OF INVESTIGATIONS No. 16

COAL ANALYSES AND LITHOLOGIC DESCRIPTIONS
OF FIVE CORE HOLES DRILLED IN THE CARBON BASIN
OF SOUTHCENTRAL WYOMING

By
Gary B. Glass



*Research sponsored by the U.S. Geological Survey,
Department of the Interior, under
Grant Number 14-08-0001-G-193.*

LARAMIE, WYOMING

1978

COAL ANALYSES AND LITHOLOGIC DESCRIPTIONS
OF FIVE CORE HOLES DRILLED IN THE
CARBON BASIN OF SOUTHCENTRAL WYOMING

by
Gary B. Glass

CONTENTS

	Page
INTRODUCTION.....	1
ACKNOWLEDGEMENTS.....	4
DRILL HOLE SITES.....	4
NOMENCLATURE AND CORRELATION OF COAL BEDS.....	5
COAL SAMPLES.....	8
COAL ANALYSES AND PHYSICAL TESTS.....	10
REFERENCES.....	31
APPENDIX A: LITHOLOGIC DESCRIPTIONS OF 5 CORE HOLES AND 2 DRILL HOLES DRILLED IN THE CARBON BASIN.....	33
APPENDIX B: GEOPHYSICAL LOGS FOR CORE HOLES WGS-C1, WGS-C2, AND WGS-C3.....	64
APPENDIX C: DETAILED MEGASCOPIC DESCRIPTIONS OF COALS ANALYZED FOR THIS REPORT.....	66

FIGURES

Figure 1. Wyoming Geological Survey's drill hole locations in the Carbon Basin.....	3
Figure 2. Tentative nomenclature for coals and coal zones in the Hanna Formation of the southern three-quarters of the Carbon Basin.....	6
Figure 3. Location of coal cores selected for analysis.....	9
Figure 4. The U.S. Geological Survey's laboratory sequence of sample preparation and chemical analysis for major and minor elements in coal.....	21
Figure 5. The U.S. Geological Survey's laboratory sequence of sample preparation and chemical analysis for trace elements in coal.....	23

Figures, cont.	Page
Figure 6. Generalized section and index map for 18 samples (Nos. 76-4 to 76-19, 77-1, and 77-2) collected in the Carbon Basin of southcentral Wyoming.....	67
Figure 7. Megascopic descriptions of the Carbon No. 6 upper and lower rider coals from Core Hole WGS-C1 (Sample Nos. 76-4 and 76-5).....	70
Figure 8. Megascopic descriptions of the Upper and Lower Carbon No. 6 coals from Core Hole WGS-C1 (Sample Nos. 76-6 and 76-7).....	73
Figure 9. Megascopic descriptions of the upper and lower benches of the Upper Carbon No. 7 from Core Hole WGS-C1 (Sample Nos. 76-8 and 76-9).....	76
Figure 10. Megascopic description of the Lower Carbon No. 7 coal from Core Hole WGS-C1 (Sample No. 76-10).....	78
Figure 11. Megascopic description of Bed No. 111 from Core Hole WGS-C1 (Sample No. 76-11).....	80
Figure 12. Megascopic descriptions of the Upper and Lower Bed No. 109 coals from Core Hole WGS-C2 (Sample Nos. 76-12 and 76-13).....	83
Figure 13. Megascopic descriptions of Upper Carbon No. 6 coal (Sample No. 76-14) and Lower Carbon No. 6 coal from Core Hole WGS-C3.....	85
Figure 14. Megascopic descriptions of the upper and lower benches of the Upper Carbon No. 7 coal (Sample Nos. 76-15 and 76-16) and the Lower Carbon No. 7 coal (Sample No. 76-17) from Core Hole WGS-C3.....	89
Figure 15. Megascopic description of Bed No. 111 from Core Hole WGS-C3 (Sample No. 76-18).....	91
Figure 16. Megascopic descriptions of the Upper (Sample No. 76-19) and Lower Bed No. 109 coals from Core Hole WGS-C3.....	93
Figure 17. Megascopic descriptions of Carbon No. 6 Rider coals (Sample No. 77-1) from Core Hole WGS-C4.....	95
Figure 18. Megascopic description of Bed No. 111 from Core Hole WGS-C4 (Sample No. 77-2).....	97

PLATES

Plate 1. Core hole and drill hole locations in the Carbon Basin of southcentral Wyoming.....	In pocket
Plate 2. Correlation of five core holes in the Carbon Basin of southcentral Wyoming.....	In pocket

Plates, cont.	Page
Plate 3. Preliminary correlation of 29 drill holes in the Carbon Basin of southcentral Wyoming.....	In pocket
Plate 4. Geophysical logs of Core Holes WGS-C1, WGS-C2, and WGS-C3.....	In pocket

TABLES

Table 1. Summary of drill hole information.....	1
Table 2. Coal samples collected for analysis.....	2
Table 3. Summary data for monitor water wells.....	3
Table 4. Distribution and thickness of major coals in the various core holes.....	11
Table 5. Analyses and physical tests performed by the various laboratories.....	13
Table 6. U.S. Geological Survey, Wyoming Geological Survey, and U.S. Bureau of Mines numbers for 18 samples from the Carbon Basin, Carbon County, Wyoming.....	14
Table 7. Proximate and ultimate analyses, heat of combustion, forms of sulfur, free-swelling index, and ash-fusion temperature determinations for 16 coal samples from the Carbon Basin, Carbon County, Wyoming	15
Table 8. Average values of proximate, ultimate, heat of combustion, and forms of sulfur analyses of 16 coal core samples from the Carbon Basin of southcentral Wyoming.....	18
Table 9. Average values of the ash-fusion temperature determinations for 16 coal core samples from the Carbon Basin of southcentral Wyoming.....	19
Table 10. Comparison of the 16 coal analyses from the Carbon Basin with 23 coal analyses from the Hanna Formation in the Hanna Basin.....	20
Table 11. Major and minor oxide and trace element composition of the laboratory ash of 18 coal samples from the Carbon Basin, Carbon County, Wyoming.....	24
Table 12. Major, minor, and trace element composition of 18 coal samples from the Carbon Basin, Carbon County, Wyoming.....	26
Table 13. Arithmetic mean, observed range, geometric mean, and geometric deviation of ash content and contents of nine major and minor oxides in the laboratory ash of 16 Carbon Basin, Carbon County, Wyoming, coal samples.....	28

Tables, cont.	Page
Table 14. Arithmetic mean, observed range, geometric mean, and geometric deviation of 37 elements in 16 Carbon Basin, Carbon County, Wyoming coal samples (whole-coal basis).....	29
Table 15. Elements looked for, but not detected in 18 coal sam- ples from the Carbon Basin of southcentral Wyoming.....	30



ADDENDUM

Proximate and ultimate analyses, heats of combustion, ash fusion temperature determinations, and forms of sulfur for Wyoming Geological Survey coal samples 77-1 and 77-2 arrived too late for inclusion in the final report. They are provided here to complete the report.

WGS Sample 77-1

PROXIMATE ANALYSIS(%)	As received	Moisture free	Moisture, ash free
Moisture	7.3	-	-
Volatile matter	37.8	40.8	46.4
Fixed Carbon	43.6	47.0	53.6
Ash	11.3	12.2	-
ULTIMATE ANALYSIS(%)			
Hydrogen	5.4	5.0	5.7
Carbon	60.6	65.4	74.4
Nitrogen	1.3	1.4	1.6
Sulfur	2.8	3.1	3.5
Oxygen	18.5	12.9	14.7
HEAT OF COMBUSTION (Btu/lb)	10,878	11,737	13,368
SULFUR FORMS(%)			
Sulfate	0.10	0.10	0.12
Pyritic	1.77	1.91	2.17
Organic	0.97	1.05	1.20
ASH FUSION TEMPERATURE (°F)			
Initial Deformation	1920		
Softening	1960		
Fluid	2000		

WGS Sample 77-2

PROXIMATE ANALYSIS(%)	As received	Moisture free	Moisture, ash free
Moisture	5.7	-	-
Volatile Matter	32.0	33.9	52.4
Fixed Carbon	29.1	30.9	47.6
Ash	33.2	35.2	-
ULTIMATE ANALYSIS(%)			
Hydrogen	4.5	4.1	6.3
Carbon	45.1	47.9	73.9
Nitrogen	1.0	1.0	1.6
Sulfur	2.1	2.2	3.4
Oxygen	14.2	9.7	15.0
HEAT OF COMBUSTION (Btu/lb.)	8,187	8,680	13,397
SULFUR FORMS(%)			
Sulfate	0.06	0.07	0.10
Pyritic	1.22	1.29	1.99
Organic	0.79	0.84	1.30
ASH FUSION TEMPERATURE (°F)			
Initial deformation	2130		
Softening	2180		
Fluid	2380		

INTRODUCTION

In the winter of 1976 and summer of 1977, the Geological Survey of Wyoming conducted a drilling project in the Carbon Basin of southcentral Wyoming. In all, 2,454.9 feet of 1-3/4-inch to 2-inch diameter cores were recovered from a total of five core holes. Another two holes were rotary-air drilled for later use as monitor water wells. Figure 1 shows the location of these holes. The types, depths, and locations of these several holes are summarized in Table 1.

Table 1: Summary drill hole information.

Drill Hole Designation	Type of Hole	Depth in Feet	Location
*WGS-C1	Core	507.7	SE $\frac{1}{4}$, Sec.34, T.22N., R.80W.
WGS-C2	Core	414.4	NW $\frac{1}{4}$, Sec.24, T.21N., R.80W.
*WGS-C2A	Rotary-Air	200.0	NW $\frac{1}{4}$, Sec.24, T.21N., R.80W.
WGS-C3	Core	620.7	SE $\frac{1}{4}$, Sec.35, T.22N., R.80W.
*WGS-C3A	Core	209.2	SE $\frac{1}{4}$, Sec.35, T.22N., R.80W.
WGS-C4	Core	702.9	NE $\frac{1}{4}$, Sec.12, T.21N., R.80W.
*WGS-C4A	Rotary-Air	310.0	NE $\frac{1}{4}$, Sec.12, T.21N., R.80W.

*Converted into monitor water wells

Lithologic descriptions of the cores and air-drilled cuttings were made in the laboratory during the winter of 1977 and spring of 1978. These descriptions are found in Appendix A.

Geophysical logs were run on portions of three of the core holes (Glass, 1976A). Although gamma, gamma-density, and resistivity were run on both Core Hole WGS-C1 and Core Hole WGS-C3, the density and resistivity logs are of no value in Core Hole WGS-C1 because they were run through the drill pipe. Because drill pipe was left in Core Hole WGS-C2 also, only a gamma log was run on that hole. The geophysical logs are reproduced in Appendix B.

Eighteen core samples of coal were described in the field, and then sent to the U.S. Geological Survey's laboratory in Denver for analysis. In turn, the U.S. Geological Survey sent a split of the

samples to the U.S. Bureau of Mines. Table 2 is a summary of the coal samples collected for analysis.

Table 2: Coal samples collected for analysis.

Core Hole Designation	Sample Number	Thickness of Sample (Ft.)	Coal Bed Name
WGS-C1	76-4	1.2	Carbon No. 6 Rider (upper)
	76-5	1.8	Carbon No. 6 Rider (lower)
	76-6	2.3	Upper Carbon No. 6
	76-7	1.6	Lower Carbon No. 6
	76-8	1.75	Upper Carbon No. 7 (upper bench)
	76-9	1.9	Upper Carbon No. 7 (lower bench)
	76-10	1.3	Lower Carbon No. 7
	76-11	4.3	Bed No. 111
WGS-C2	*76-12	5.8	Upper Bed No. 109
	76-13	1.95	Lower Bed No. 109
WGS-C3	76-14	6.2	Upper Carbon No. 6
	76-15	1.7	Upper Carbon No. 7 (upper bench)
	76-16	1.7	Upper Carbon No. 7 (lower bench)
	76-17	2.0	Lower Carbon No. 7
	76-18	3.4	Bed No. 111
	76-19	3.8	Upper Bed No. 109
WGS-C4	77-1	1.95	Carbon No. 6 Rider
	77-2	3.2	Bed No. 111

*A portion of this bed was not analyzed

While the U.S. Bureau of Mines performed routine analyses and physical tests on the samples, the U.S. Geological Survey determined concentrations of major, minor, and trace elements. To compliment each of the analyses, a detailed megascopic description of each coal sample is provided in Appendix C.

It is stressed at the onset that there are not enough analyses in this report to characterize any individual coals in the Carbon Basin. Summary tables, combining analyses, are provided only for comparison of these analyzed samples. Characterization of individual coals is deferred until additional analyses are available.

Monitor water wells were also constructed at each core hole site. Except for Core Hole WGS-C1, which was converted directly into a water well, the construction of these monitor wells required the drilling of a second hole near each core hole location. Table 3 summarizes the

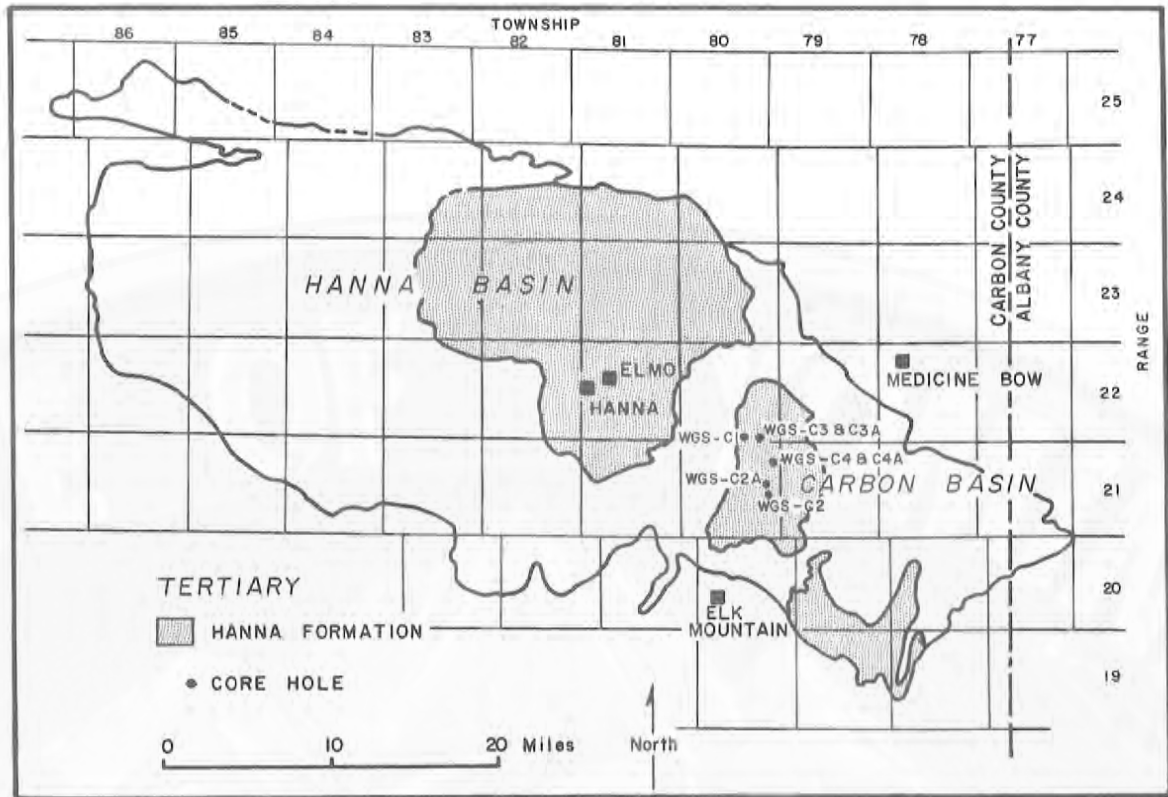


Figure 1. Wyoming Geological Survey's drill hole locations in the Carbon Basin.

depths, casing lengths, depths to first water, and locations of these water wells.

Table 3: Summary data for monitor water wells

Water Well Designation	Depth in Feet	Casing Length in Feet	Depth to First Water in Feet	Location
WGS-C1	510.0	310	145±	SE $\frac{1}{4}$, Sec.34, T.22N., R.80W.
WGS-C2A	200.0	200	95	NW $\frac{1}{4}$, Sec.24, T.21N., R.80W.
*WGS-C3A	209.2	175	Unknown	SE $\frac{1}{4}$, Sec.35, T.22N., R.80W.
WGS-C4A	310.0	220	128	NE $\frac{1}{4}$, Sec.12, T.21N., R.80W.

*Cored

ACKNOWLEDGEMENTS

This research was funded by a grant from the Conservation Division of the U.S. Geological Survey. Program Manager was Elmer M. Schell, Regional Geologist, in Casper, Wyoming. This financial assistance is gratefully acknowledged.

I would also like to acknowledge the fine analytical work provided by Forrest E. Walker's Coal Analysis Section of the Department of Energy (formerly a part of the U.S. Bureau of Mines) in Pittsburgh, Pennsylvania, and by analysts J.W. Baker, N.M. Conklin, C.M. Ellis, P.G. Guest, R.J. Knight, C. McFee, R.E. McGregor, V. Merritt, H.T. Millard, Jr., H.G. Neiman, G.D. Shipley, V.C. Smith, J.A. Thomas, and J.S. Wahlberg of the U.S. Geological Survey's Branch of Analytical Laboratories in Denver, Colorado. The help of Vernon Swanson and Joseph Hatch of the U.S. Geological Survey's Branch of Coal Resources is also appreciated. Most of the tabulated analytical data and statistical summary tables were provided by these men.

The drilling contractor was Geck, Incorporated of Rock Springs, Wyoming. Geophysical logs were run by Peter Kiewit Sons' Company, Omaha, Nebraska, and Rocky Mountain Energy Company, Denver, Colorado. In particular, I would like to thank Thomas A. Gwynn, Glen Miller, and B. Kristiansen of Peter Kiewit, and David B. Corman and L.R. Sherman of Rock Mountain Energy for their assistance, time, and equipment.

Field assistance was ably provided by University of Wyoming students, Jay Roberts and Ken Brooks.

Last but not least, I want to thank Harry Chace, owner of the Chase Ranch, Miles A. Williams, President of Anschutz Land and Livestock Company, Inc., and John Brown, Manager--Coal Evaluation for Rocky Mountain Energy Company not only for allowing me access to the drill hole sites, but for putting up with a multitude of inconveniences that I am not going to mention here.

DRILL HOLE SITES

All seven drill hole sites were located in the Carbon Basin, a small synclinal depression southeast of the larger Hanna Basin of

southcentral Wyoming (Figure 1). Both basins are included in the Hanna Coal Field of the Rocky Mountain Coal Province. Although coals in the Carbon Basin occur in the Hanna, Ferris, Medicine Bow, and Mesaverde formations, only the Paleocene age Hanna Formation was penetrated by the drilling done for this investigation. For this reason, the interested reader is referred to Dobbin and others (1929), Hyden and McAndrews (1967), Gill, and others (1970) and Glass (1972), for discussions of coals in the other formations, which are all older than the Hanna Formation.

The four longest core holes in this study (WGS-C1, -C2, -C3, and -C4) are positioned in the Hanna Formation. They are south of one another by one to two miles (Figure 1). A shorter, fifth core hole (WGS-C3A) was drilled within 25 feet of Core Hole WGS-C3 to replace a zone of poor recovery at the top of WGS-C3. Rotary drill holes WGS-C2A and WGS-C4A were drilled adjacent to Core Holes WGS-C2 and WGS-C4 and left as monitor water wells. Again, Table 1 summarizes information on each of these seven drill holes.

The core holes drilled for this investigation penetrated the uppermost 1,000 feet of the Hanna Formation in the Carbon Basin. In late 1977, Hettinger (1978) drilled 24 additional test holes north and south of the seven holes described here (Plate 1). When the drilling from this investigation was correlated with Hettinger's (1978) drilling, the author concluded that the Hanna Formation is at least 2,400 feet thick near the center of the Carbon Basin, perhaps thicker. Previous investigators had estimated the Hanna Formation thickness at less than 1,300 feet (Dobbin, and others, 1929; Gill, and others, 1970).

NOMENCLATURE AND CORRELATION OF COAL BEDS

Unfortunately, once the 2,400 feet thick section of the Hanna Formation was recognized in the Carbon Basin, it was immediately apparent that the coal correlations of Dobbin and others (1929) were incorrect. At least two, and perhaps many more faults that dissect the basin add further complications (Plate 1). Because Dobbin and others (1929) were not aware of these faults, their correlations northward and southward in the basin were wrong. These miscorrelations led to their conclusion that the basin contained less than 1,300 feet of the Hanna Formation.

CARBON BASIN

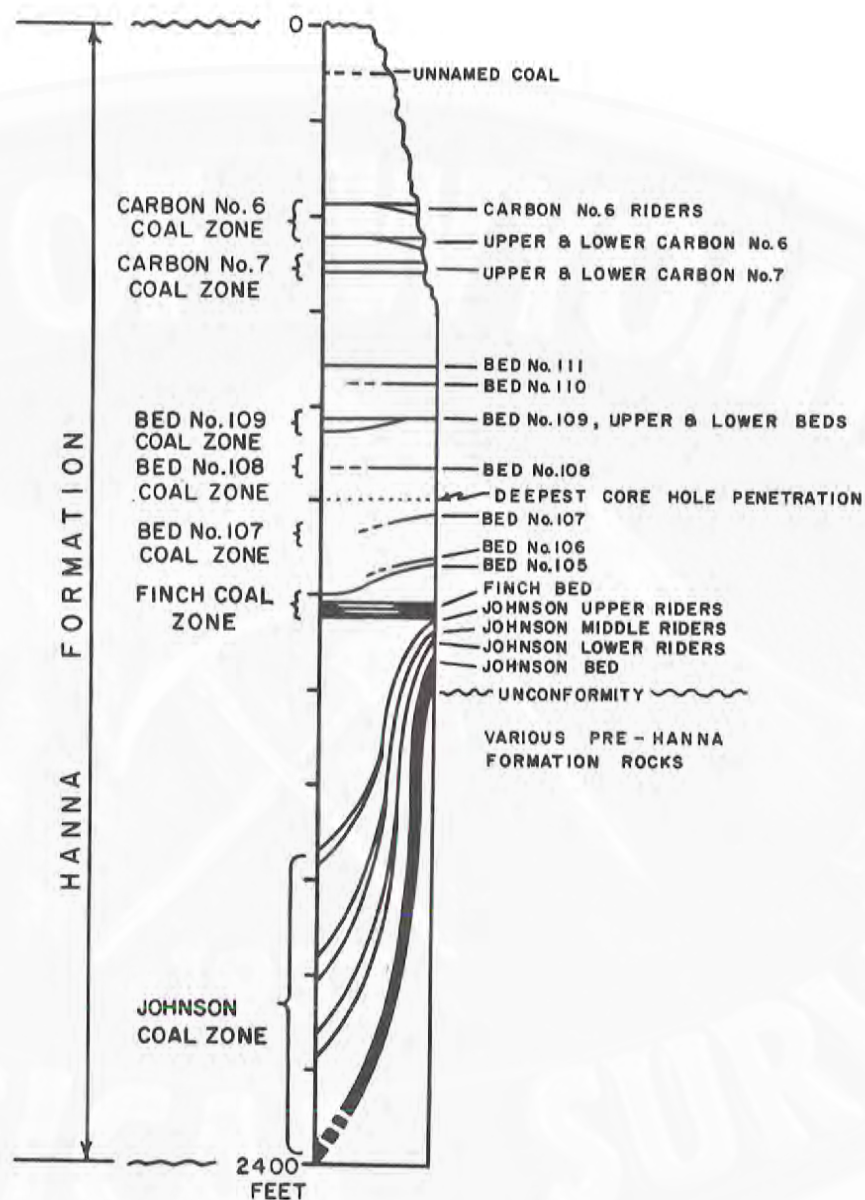


Figure 2. Tentative nomenclature for coals and coal zones in the Hanna Formation of the southern three-quarters of the Carbon Basin.

As examples, the coal beds numbered 109, 110, and 111, by Dobbin, and others (1929) reportedly occur above the Carbon No. 6 and No. 7 coal beds, which supposedly are correlative with Bed No. 108 and possibly Bed No. 107. This recent drilling shows that the Carbon No. 6 and Carbon No. 7 coals not only don't equate with Bed No. 108 or Bed No. 107, but that the Carbon No. 6 and No. 7 beds occur 200 - 300 feet above Bed No. 111 as it is defined at the south end of the basin (Figure 2).

In an effort to salvage as much of the older coal nomenclature of the basin as possible, the tentative nomenclature of Figure 2 is proposed. In essence, there is no difference between this nomenclature and that of Dobbin, and others (1929). The apparent discrepancy that puts the Carbon No. 7 and No. 6 beds above Bed No. 111 simply corrects an error in correlation caused by unrecognized faulting. Unfortunately, none of the recent test holes was far enough north to resolve correlation of the Carbon No. 4 and No. 5 beds of Dobbin, and others (1929). These coal beds may well correlate with the Finch and Johnson coals as the earlier workers suggested, but proof of this must await additional drilling.

The upper six coals or coal zones on Figure 2 are defined on the basis of the seven holes drilled for this investigation. In descending order of occurrence, these units are the Carbon No. 6 coal zone, the Carbon No. 7 coal zone, Bed No. 111, Bed No. 110, the Bed No. 109 coal zone, and the Bed No. 108 coal zone. Each coal zone is either comprised of splits off a single coal or two or more coals that are close enough together or show enough affinity to one another to warrant similar names. The additional drilling by Hettinger (1978) was used to define the three lower coal zones: the Bed No. 107 coal zone, the Finch coal zone, and the Johnson coal zone.

Plate 2 is a correlation diagram for the five core holes drilled by the Geological Survey of Wyoming (Core Holes WGS-C3 and -C3A are composited). Information from the two additional rotary drill holes was used to augment the core hole descriptions when necessary. Plate 3 is a correlation diagram that ties the test holes from this investigation into those drilled by Hettinger (1978). Correlations on both these plates are the author's. It should also be noted that the seven

holes drilled for this investigation were not correctly correlated until Hettinger's (1978) test hole descriptions and geophysical logs became available. Table 4 lists the thickness for each of the major coal beds encountered in the core holes.

COAL SAMPLES

During the drilling, 18 coal cores, representing all or portions of four of the major coal horizons in the upper 1,000 feet of the Hanna Formation, were selected and removed for analysis (Figure 3). Overall, six samples were selected from the Carbon No. 6 coal zone, six samples were from the Carbon No. 7 coal zone, three samples were of Bed No. 111, and three samples were from the Bed No. 109 coal zone. Samples of Bed No. 110 and Bed No. 108 were not selected for analysis because of their poor development in these core holes.

All selected coal samples were carefully placed in plastic bags immediately after their recovery. Usually, detailed megascopic descriptions of the samples were made in the Survey's laboratory in Laramie the same evening the core was recovered or within 48 hours after recovery. After the samples were described, they were placed in new plastic bags and stored in air-tight metal containers to await shipment to the U.S. Geological Survey's laboratories in Denver. Small fragments (2-5 grams) of each megascopically different portion of a sample were retained by the Geological Survey of Wyoming for possible palynological examination at a later date.

With few exceptions, each selected coal sample represents the entire thickness of a major coal bed or bench of a major coal bed (Table 2). Noncoaly material (partings or pyrite lenses) were left in the samples unless they were thick enough that a mining company might reasonably be able to remove them during mining. This deviates from more conventional procedures that require a sampler to pick out and discard all partings of shale, pyrite, or other noncoaly material greater than 3/8 inches thick--in essence cleaning the coal (Schopf, 1960). This more conventional practice was avoided because Wyoming's coals are not cleaned after mining. Since the analyses of "as-used" coals are as important to the prediction of plant emissions as they are

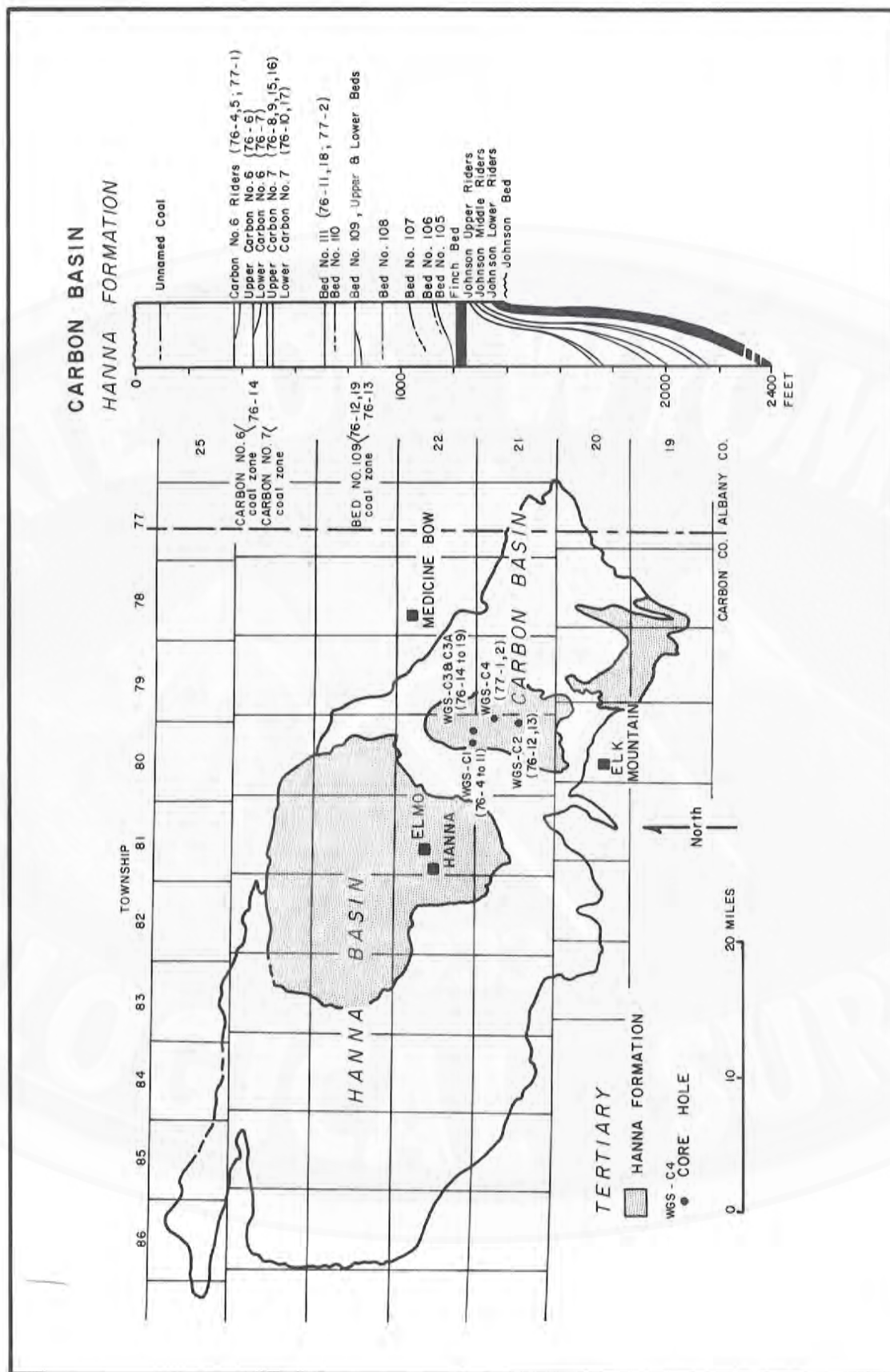


Figure 3. Location of coal cores selected for analysis.

to the prediction of its combustion behavior in those plants, the removal of mined impurities could lessen the value of the analyses for both these concerns.

The most notable exceptions to this procedure were Sample No. 76-18 and Sample No. 76-19. In both cases, thick clayey partings (0.7 feet thick and 1.25 feet thick, respectively) were left in the samples to see their effect on the coal's quality.

Even a quick examination of Table 2 should call attention to the sample thicknesses. Only six of the selected samples were over three feet thick. The twelve thinner coals that were selected were chosen for several reasons. Firstly, after the six thickest coals were sampled, only thin coals remained. Secondly, many of these thinner coals appeared to be clean enough that they might be minable in conjunction with a thicker bed. Thirdly, other drill holes in the basin indicated that some of these thin beds were thick enough to mine in other portions of the basin. Because of this, some thin expressions of coals were sampled to provide an indication of what their quality might be elsewhere. Fourthly, some thin coals were selected simply to provide analytical data on a suite of coals that are traditionally never selected for analysis.

COAL ANALYSES AND PHYSICAL TESTS

Coal analyses and physical tests were performed by either the U.S. Bureau of Mines' Coal Analysis Section (now part of Department of Energy) in Pittsburgh, Pennsylvania, or the U.S. Geological Survey's Branch of Analytical Laboratories in Denver, Colorado. Table 5 shows which analyses or tests were done by each of the laboratories. Table 6 equates the various sample numbers used by the Wyoming Geological Survey, U.S. Geological Survey, and U.S. Bureau of Mines.

The routine proximate and ultimate analyses, heats of combustion, forms of sulfur, free-swelling indices, and ash fusion temperatures of 16 of the Carbon Basin samples are given in Table 7. The analytical methods used by the U.S. Bureau of Mines are described in U.S. Bureau of Mines Bulletin 638 (Office of Coal Research, 1967).

Tables 8 and 9 give the average value (arithmetic mean) of the routine coal analyses and physical tests by major coal or coal zone.

Table 4: Distribution and thickness of major coals in the various core holes.

COAL NAME	CORE INTERVAL IN FEET	THICKNESS IN FEET	SAMPLE NUMBER(S)
Core Hole WGS-C1			
Carbon No. 6 Rider (upper)	159.0-160.2	1.2	76-4
Carbon No. 6 Rider (lower)	164.3-166.1	1.8	76-5
Upper Carbon No. 6	214.7-217.0	2.3	76-6
Lower Carbon No. 6	220.3-221.9	1.6	76-7
Upper Carbon No. 7 (two benches)	273.8-277.8	4.0	76-8,9
Lower Carbon No. 7	294.3-295.6	1.3	76-10
Bed No. 111	488.7-493.0	4.3	76-11
Core Hole WGS-C2 & C2A			
Bed No. 111	43.0-44.0	1.0	-
Bed No. 110	70.6-70.9	0.3	-
Upper and Lower Bed No. 109 (combined)	100.9-110.95	10.05	76-12,13
Bed No. 108	276.0-277.2	1.2	-
Core Hole WGS-C3 & C3A			
Carbon No. 6 Rider	134.3-135.3	1.0	-
Upper and Lower Carbon No. 6 (combined)	232.5-241.0	8.5	76-14
Upper Carbon No. 7 (Two benches)	268.1-272.0	3.9	76-15,16
Lower Carbon No. 7	283.2-285.2	2.0	76-17
Bed No. 111	448.6-452.0	3.4	76-18
Upper Bed No. 109	566.8-570.6	3.8	76-19
Lower Bed No. 109	479.6-580.6	1.0	-
Core Hole WGS-C4			
Carbon No. 6 Rider	64.0-65.95	1.95	77-1
Carbon No. 6 Rider	68.3-69.2	0.9	-
Carbon No. 6 Rider	73.7-74.8	1.1	-
Upper Carbon No. 6	86.5-87.9	1.4	-
Lower Carbon No. 6	106.4-107.3	0.9	-
Carbon No. 7 Rider	142.3-143.8	1.5	-
Upper Carbon No. 7	147.3-148.8	1.5	-
Lower Carbon No. 7	154.9-157.0	2.1	-
Bed No. 111	314.4-317.6	3.2	77-2
Upper Bed No. 109	418.0-419.8	1.8+	-
Lower Bed No. 109	428.9-429.5	0.6	-

These average values should not be construed as characterizing any given bed or zone, but are presented only for comparison of these 16 analyses. An average analysis for the three thickest coals (4.3-6.2 feet thick) is also provided in Table 8.

Three notable observations are readily apparent from an examination of the individual analyses as well as the tables of average values. Firstly, these coal samples have relatively high ash contents that vary from 9.5-51.6 percent on an as received basis, averaging 28.5 percent. Two of the samples are high enough in ash not to be called coals (76-7 and 76-19). Secondly, on an as received basis, all but one of the samples have relatively high sulfur contents. These sulfur contents vary from 1.5-8.7 percent and average 3.5 percent. The exception (76-19), which is a high ash (50.9 percent) sample with 0.9 percent sulfur, is best not even called a coal. Thirdly, pyrite is the dominant form of sulfur identified in the samples and usually occurs in concentrations twice as large as the organic form, averaging 2.39 percent and 1.05 percent, respectively.

Although these traits are not typical of the Hanna Formation coals currently mined in the nearby Hanna District of the Hanna Coal Field, it should be noted that the 16 samples from the Carbon Basin were (1) selected randomly without regard to their economic value and (2) much thinner than the coals mined at Hanna (Table 10). These two factors alone can account for the apparent disparity in coal quality between the two basins. True characterization of the coal quality in the Carbon Basin must await additional investigation. Conversely, true characterization of the coals of the Hanna Basin awaits the incorporation of analyses of thinner unmined coals to go along with the analyses of mined beds.

The U.S. Geological Survey determined concentrations of 10 major and minor elements in the Carbon Basin samples (Table 5). In these analyses the coal was ashed in the laboratory at 525° C. The U.S. Geological Survey's sequence of sample preparation and chemical analysis is shown in Figure 4. Tables 11 and 12, respectively, give the results of these analyses as percent oxides in ash and as percent elements calculated back to whole-coal. Table 13 gives the range and average values for nine of the oxides of the ash (P_2O_5 omitted), and Table 14 does the same on the whole-coal basis.

Table 5. Analyses and physical tests performed by the various laboratories.

U.S. Bureau of Mines

Proximate analysis (percent)

Moisture
Volatile matter
Fixed carbon
Ash

Ultimate analysis (percent)

Hydrogen (H)
Carbon (C)
Nitrogen (N)
Oxygen (O)
Sulfur (S)
Ash

Heat value (Btu/pound; Kcal/Kg)

Forms of Sulfur (percent)

Sulfate
Pyritic
Organic

Fusibility of ash (Temp. °F & °C)

Initial deformation
Softening temperature
Fluid temperature

Free-swelling index

U.S. Geological Survey

Major and minor elements (percent)¹

Silicon (Si)
Aluminum (Al)
Calcium (Ca)
Magnesium (Mg)
Sodium (Na)
Potassium (K)
Iron (Fe)
Manganese (Mn)
Titanium (Ti)
Phosphorous (P)
Sulfur (S)

Trace elements (ppm)²

Arsenic (As)
Beryllium (Be)
Boron (B)
Barium (Ba)
Cadmium (Cd)
Cerium (Ce)
Cobalt (Co)
Chromium (Cr)
Copper (Cu)
Fluorine (F)
Gallium (Ga)
Mercury (Hg)
Lanthanum (La)
Lithium (Li)
Molybdenum (Mo)
Niobium (Nb)
Neodymium (Nd)
Nickel (Ni)
Lead (Pb)
Antimony (Sb)
Scandium (Sc)
Selenium (Se)
Silver (Ag)
Strontium (Sr)
Thorium (Th)
Uranium (U)
Vanadium (V)
Yttrium (Y)
Ytterbium (Yb)
Zinc (Zn)
Zirconium (Zr)

¹ Reported as oxides in 525°C laboratory ash as well as on a whole-coal basis

² Reported as ppm on a whole-coal basis and/or in 525°C laboratory ash

Table 6: U.S. Geological Survey, Wyoming Geological Survey and U.S. Bureau of Mines numbers for 18 samples from the Carbon Basin, Carbon County, Wyoming.

W.G.S. number	U.S.B.M. number	U.S.G.S. number	COAL BED NAME	SAMPLE THICKNESS
76-4	K72359	D188040	Carbon No. 6 Rider (upper)	1.2'
76-5	K72360	D188041	Carbon No. 6 Rider (lower)	1.8'
76-6	K72361	D188042	Upper Carbon No. 6	2.3'
76-7	K72362	D188043	Lower Carbon No. 6	1.6'
76-8	K72363	D188044	Upper Carbon No. 7 (upper bench)	1.75'
76-9	K72364	D188045	Upper Carbon No. 7 (lower bench)	1.9'
76-10	K72365	D188046	Lower Carbon No. 7	1.3'
76-11	K72366	D188047	Bed No. 111	4.3'
76-12	K72367	D188048	Upper Bed No. 109	5.8'
76-13	K72368	D188049	Lower Bed No. 109	1.95'
76-14	K72369	D188050	Upper Carbon No. 6	6.2'
76-15	K72370	D188051	Upper Carbon No. 7 (upper bench)	1.7'
76-16	K72371	D188052	Upper Carbon No. 7 (lower bench)	1.7'
76-17	K72372	D188053	Lower Carbon No. 7	2.0'
76-18	K72373	D188054	Bed No. 111	3.4'
76-19	K72374	D188055	Upper Bed No. 109	3.8'
77-1	-	D194472	Carbon No. 6 Rider	1.95'
77-2	-	D194473	Bed No. 111	3.2'

Table 7.--Proximate and ultimate analyses, heat of combustion, forms of sulfur, free-swelling index and ash-fusion temperature determinations for 16 coal samples from the Carbon Basin, Carbon County, Wyo.

[All analyses except Kcal/kg, Btu/lb, free-swelling index and ash-fusion temperatures in percent. For each sample number, the analyses are reported three ways; first, as received, second, moisture-free, and third, moisture and ash-free. All analyses by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, Pa. B means not determined. °C = (°F-32) 5/9; Kcal/kg = 0.556 (Btu/lb)]

Sample numbers	Proximate Analysis				Ultimate Analysis				Heat of Combustion		
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D188040 (76-4)	7.6 --- ---	35.2 38.1 50.4	34.7 37.6 49.6	22.5 24.4 ---	5.1 4.6 6.1	52.8 57.1 75.5	1.2 1.3 1.7	15.8 9.8 12.9	2.7 2.9 3.9	5,330 5,770 7,630	9,600 10,390 13,740
D188041 (76-5)	10.0 --- ---	34.2 38.0 49.2	35.3 39.2 50.8	20.5* 22.8 ---	5.2 4.5 5.9	51.9 57.7 74.7	1.0 1.1 1.4	16.2 8.1 10.5	5.2 5.8 7.5	5,280 5,870 7,600	9,500 10,560 13,670
D188042 (76-6)	13.4 --- ---	32.3 37.3 46.0	38.0 43.9 54.1	16.4 18.9 ---	5.5 4.6 5.7	53.8 62.1 76.6	1.1 1.3 1.6	20.9 10.4 12.8	2.3 2.7 3.3	5,330 6,150 7,590	9,590 11,070 13,660
D188043 (76-7)	7.5 --- ---	22.8 24.6 55.7	18.1 19.6 44.3	51.6 55.8 ---	3.4 2.8 6.3	28.7 31.0 70.2	.7 .8 1.7	12.8 6.6 15.0	2.7 2.9 6.6	2,850 3,090 6,980	5,140 5,550 12,560
D188044 (76-8)	7.3 --- ---	26.5 28.6 52.9	23.6 25.5 47.1	42.6 46.0 ---	3.6 3.0 5.6	32.8 35.4 65.5	.7 .8 1.4	11.7 5.6 10.4	8.7 9.4 17.4	3,490 3,770 6,970	6,280 6,780 12,540
D188045 (76-9)	7.7 --- ---	30.4 32.9 51.7	28.4 30.8 48.3	33.5 36.3 ---	4.5 3.9 6.2	41.9 45.4 71.3	.9 1.0 1.5	13.0 6.7 10.5	6.2 6.7 10.5	4,290 4,650 7,300	7,720 8,370 13,130
D188046 (76-10)	8.8 --- ---	35.5 38.9 49.4	36.3 39.8 50.6	19.4 21.3 ---	5.3 4.7 6.0	54.2 59.4 75.5	1.3 1.4 1.8	16.7 9.7 12.4	3.0 3.3 4.2	5,460 5,990 7,600	9,830 10,780 13,690
D188047 (76-11)	13.2 --- ---	27.4 31.6 58.3	19.6 22.6 41.7	39.8 45.9 ---	4.7 3.7 6.9	34.7 40.0 73.8	.8 .9 1.7	18.1 7.3 13.5	1.9 2.2 4.0	3,520 4,050 7,480	6,330 7,290 13,460
D188048 (76-12)	8.5 --- ---	33.3 36.4 51.4	31.5 34.4 48.6	26.7 29.2 ---	4.8 4.2 5.9	48.5 53.0 74.8	1.1 1.2 1.7	16.5 9.8 13.8	2.4 2.6 3.7	4,820 5,260 7,430	8,670 9,470 13,380
D188049 (76-13)	7.7 --- ---	36.1 39.1 54.4	30.2 32.7 45.6	26.0 28.2 ---	5.0 4.5 6.3	49.2 53.3 74.2	1.0 1.1 1.5	14.7 8.5 11.8	4.0 4.3 6.0	5,000 5,410 7,540	8,990 9,740 13,570
D188050 (76-14)	10.0 --- ---	33.3 37.0 49.4	34.1 37.9 50.6	22.6 25.1 ---	5.2 4.5 6.1	51.4 57.1 76.3	1.0 1.1 1.5	17.8 9.9 13.2	1.9 2.1 2.8	5,130 5,700 7,620	9,240 10,270 13,710
D188051 (76-15)	11.7 --- ---	30.6 34.7 50.6	29.9 33.9 49.4	27.8 31.5 ---	4.9 4.1 6.0	43.9 49.7 72.6	.9 1.0 1.5	17.3 7.8 11.4	5.1 5.8 8.4	4,480 5,080 7,410	8,070 9,140 13,340

Table 7.--Proximate and ultimate analyses, heat of combustion, forms of sulfur, free-swelling index and ash-fusion temperature determinations for 16 coal samples from the Carbon Basin, Carbon County, Wyo.--Continued

Sample numbers	Proximate Analysis				Ultimate Analysis				Heat of Combustion		
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D188052 (76-16)	11.0 --- ---	36.4 40.9 45.8	43.1 48.4 54.2	9.5 10.7 ---	5.6 4.9 5.5	59.5 66.9 74.8	1.2 1.3 1.5	19.3 10.7 12.0	4.9 5.5 6.2	6,010 6,750 7,560	10,810 12,150 13,600
D188053 (76-17)	10.4 --- ---	36.9 41.2 47.7	40.5 45.2 52.3	12.2 13.6 ---	5.5 4.8 5.6	59.6 66.5 77.0	1.2 1.3 1.6	19.9 11.9 13.8	1.5 1.7 1.9	5,860 6,540 7,580	10,550 11,780 13,640
D188054 (76-18)	8.6 --- ---	30.8 33.7 53.6	26.7 29.2 46.4	33.9 37.1 ---	4.6 4.0 6.3	43.3 47.4 75.3	.9 1.0 1.6	14.7 7.7 12.3	2.6 2.8 4.5	4,360 4,770 7,590	7,850 8,590 13,650
D188055 (76-19)	9.8 --- ---	21.4 23.7 54.5	17.9 19.8 45.5	50.9 56.4 ---	3.7 2.9 6.6	28.9 32.0 73.5	.6 .7 1.5	14.9 6.9 15.7	.9 1.0 2.3	2,820 3,120 7,170	5,070 5,620 12,910
Sample numbers	Air-dried loss	Forms of sulfur			Ash fusion temperature °C (°F)						
		Sulfate	Pyritic	Organic	Initial deform.	soften.	fluid				
D188052 (76-16)	5.1 --- ---	0.29 .33 .36	3.53 3.97 4.44	1.03 1.16 1.30	1,205 (2,220)	1,215 (2,220)	1,265 (2,310)				
D188053 (76-17)	4.8 --- ---	.01 .01 .01	.74 .83 .96	.78 .87 1.01	1,215 (2,220)	1,265 (2,310)	1,325 (2,420)				
D188054 (76-18)	3.5 --- ---	.06 .07 .10	1.99 2.18 3.46	.56 .61 .97	1,180 (2,160)	1,235 (2,250)	1,295 (2,360)				
D188055 (76-19)	4.8 --- ---	.01 .01 .03	.61 .68 1.55	.28 .31 .71	1,430 (2,610)	1,495 (2,720)	1,540 (2,800)				

Table 7. --Proximate and ultimate analyses, heat of combustion, forms of sulfur, free-swelling index and ash-fusion temperature determinations for 16 coal samples from the Carbon Basin, Carbon County, Wyo.--Continued

Sample numbers	Air-dried loss	Forms of sulfur			Free swelling	Ash fusion temperature °C (°F)		
		Sulfate	Pyritic	Organic		Initial deform.	soften.	fluid
D188040 (76-4)	1.8 --- ---	0.01 .01 .01	1.67 1.81 2.39	0.99 1.07 1.42	0.0	1,125 (2,060)	1,185 (2,160)	1,250 (2,280)
D188041 (76-5)	4.7 --- ---	.01 .01 .01	4.16 4.62 5.99	1.02 1.13 1.47	.0	1,065 (1,920)	1,125 (2,060)	1,165 (2,130)
D188042 (76-6)	7.9 --- ---	.01 .01 .01	1.64 1.89 2.34	.61 .70 .87	.0	1,120 (2,050)	1,195 (2,180)	1,250 (2,280)
D188043 (76-7)	2.7 --- ---	.01 .01 .02	2.37 2.56 5.79	.35 .38 .86	.0	1,320 (2,400)	1,375 (2,510)	1,435 (2,580)
D188044 (76-8)	2.9 --- ---	.25 .27 .50	6.21 6.70 12.40	2.21 2.38 4.41	.0	1,070 (1,960)	1,120 (2,050)	1,165 (2,130)
D188045 (76-9)	2.4 --- ---	.02 .02 .03	3.20 3.47 5.44	3.00 3.25 5.10	.0	1,095 (2,000)	1,145 (2,090)	1,205 (2,200)
D188046 (76-10)	B --- ---	.01 .01 .01	1.45 1.59 2.02	1.56 1.71 2.17	.0	1,155 (2,110)	1,205 (2,200)	1,265 (2,310)
D188047 (76-11)	9.0 --- ---	.02 .02 .04	1.23 1.42 2.62	.65 .75 1.38	.0	1,290 (2,350)	1,345 (2,450)	1,400 (2,550)
D188048 (76-12)	2.2 --- ---	.02 .02 .03	1.40 1.53 2.16	.99 1.08 1.53	.0	1,180 (2,160)	1,235 (2,250)	1,290 (2,350)
D188049 (76-13)	1.8 --- ---	.01 .01 .02	3.60 3.90 5.43	.39 .42 .59	.0	1,130 (2,070)	1,185 (2,160)	1,240 (2,260)
D188050 (76-14)	4.8 --- ---	.02 .02 .03	.82 .91 1.22	1.08 1.20 1.60	.0	1,150 (2,100)	1,210 (2,210)	1,265 (2,310)
D188051 (76-15)	7.4 --- ---	.18 .20 .30	3.59 4.07 5.93	1.37 1.55 2.26	.0	1,150 (2,100)	1,205 (2,200)	1,270 (2,320)

Table 8. Average values of proximate, ultimate, heat of combustion, and forms of sulfur analyses of 16 coal samples from the Carbon Basin of southcentral Wyoming.

NUMBER AVERAGED	PROXIMATE ANALYSIS (PERCENT)			ULTIMATE ANALYSIS (PERCENT)						SULFUR FORMS (PERCENT)			HEAT OF COMBUSTION (Btu/lb)	Basals ¹
	MOISTURE	VOLATILE MATTER	FIXED CARBON	ASH	H	C	N	O	S	SULFATE	PYRITIC	ORGANIC		
Carbon No. 6 coal zone														
5	9.7	31.6	32.0	26.7	4.9	47.7	1.0	16.7	3.0	.01	2.13	0.81	8,610	1
	-	35.0	35.6	29.4	4.2	53.0	1.1	9.0	3.3	.01	2.36	0.90	9,570	2
	-	50.1	49.9	-	6.0	74.7	1.6	12.9	4.8	.02	3.55	1.24	13,470	3
Carbon No. 7 coal zone														
6	9.5	32.7	33.6	24.2	4.9	48.7	1.0	16.3	4.9	0.13	3.12	1.66	8,880	1
	-	36.2	37.3	26.6	4.2	53.9	1.1	8.7	5.5	0.14	3.44	1.82	9,830	2
	-	49.7	50.3	-	5.8	72.8	1.5	11.7	8.1	0.20	5.20	2.71	13,320	3
Bed No. 111														
2	10.9	29.1	23.1	36.8	4.6	39.0	0.9	16.4	2.2	0.04	1.61	0.60	7,090	1
	-	32.6	25.9	41.5	3.8	43.7	0.9	7.5	2.5	0.04	1.80	0.68	7,940	2
	-	55.9	44.0	-	6.6	74.5	1.7	12.9	4.2	0.07	3.04	1.17	13,550	3
Bed No. 109 coal zone														
3	8.7	30.3	26.5	34.5	4.5	42.2	0.9	15.4	2.4	0.01	1.87	0.55	7,580	1
	-	33.1	29.0	37.9	3.9	46.1	1.0	8.4	2.6	0.01	2.04	0.60	8,090	2
	-	53.4	46.6	-	6.3	74.2	1.6	13.8	4.0	0.03	3.05	0.94	13,290	3
All coals and coal zones combined														
16	9.6	31.4	30.5	28.5	4.8	45.9	1.0	16.3	3.5	0.05	2.39	1.05	8,410	1
	-	34.8	33.8	31.4	4.1	50.9	1.1	8.6	3.9	0.06	2.63	1.16	9,220	2
	-	51.3	48.7	-	6.1	73.8	1.6	12.6	5.8	0.09	4.01	1.73	13,390	3
Three coals greater than 4 feet thick (76-11, 76-12, 76-14)														
3	10.6	31.3	28.4	29.7	4.9	44.9	1.0	17.5	2.1	0.02	1.15	0.91	8,080	1
	-	35.0	31.6	33.4	4.1	50.0	1.1	9.0	2.3	0.02	1.29	1.01	9,010	2
	-	53.0	47.0	-	6.3	75.0	1.6	13.5	3.5	0.03	2.00	1.50	13,520	3

¹ The analyses are reported as 1, sample as received; 2, sample moisture-free (dry); and 3, sample moisture and ash-free (dry, ash-free)

Note: These statistical summaries are not to be construed as necessarily characterizing any coal or coal zone, but are presented as an aid to comparing these 16 analyses.

Table 9. Average values of the ash-fusion temperature determinations for 16 coal core samples from the Carbon Basin of southcentral Wyoming.

NUMBER AVERAGED	ASH FUSION TEMPERATURE			
	INITIAL DEFORMATION	SOFTENING TEMPERATURE	FLUID TEMPERATURE	
Carbon No. 6 coal zone 5	1,160 (2,110)	1,220 (2,220)	1,270 (2,320)	$^{\circ}\text{C}$ $^{\circ}\text{F}$
Carbon No. 7 coal zone 6	1,150 (2,100)	1,190 (2,180)	1,250 (2,280)	$^{\circ}\text{C}$ $^{\circ}\text{F}$
Bed No. 111 2	1,230 (2,250)	1,290 (2,350)	1,350 (2,450)	$^{\circ}\text{C}$ $^{\circ}\text{F}$
Bed No. 109 coal zone 3	1,250 (2,280)	1,300 (2,380)	1,360 (2,470)	$^{\circ}\text{C}$ $^{\circ}\text{F}$
All coals and coal zones combined 16	1,180 (2,150)	1,230 (2,250)	1,290 (2,350)	$^{\circ}\text{C}$ $^{\circ}\text{F}$

Note: These statistical summaries are not to be construed as necessarily characterizing any coal or coal zone, but are presented as an aid to comparing these 16 analyses.

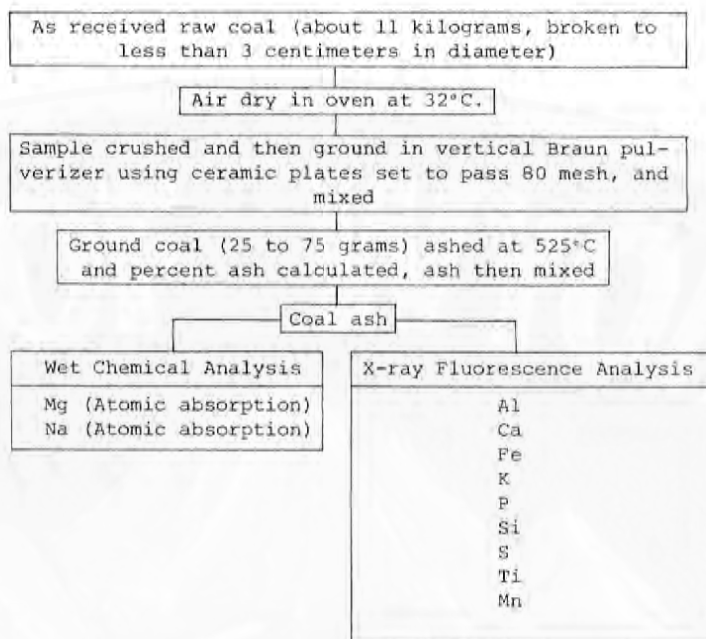
Table 10: Comparison of the 16 coal analyses from the Carbon Basin with 23 coal analyses from the Hanna Formation in the Hanna Basin.

As received Basis	CARBON BASIN		HANNA BASIN	
	Range	Average	Range	Average
Moisture (%)	7.3-13.4	9.6	6.3-14.5 ¹	10.9 ¹
Volatile Matter (%)	21.4-36.9	31.4	32.6-41.1 ¹	38.2 ¹
Fixed Carbon (%)	17.9-43.1	30.5	34.1-47.6 ¹	42.8 ¹
Ash (%)	9.5-51.6	28.5	4.4-23.8 ¹	8.2 ¹
Sulfur (%)	0.9-8.7	3.5	0.26-1.2 ¹	0.62 ¹
Sulfate Sulfur (%)	0.01-0.29	0.05	0.01-0.03 ²	0.02 ²
Pyritic Sulfur (%)	0.61-6.21	2.39	0.15-0.44 ²	0.30 ²
Organic Sulfur (%)	0.28-3.00	1.05	0.21-0.69 ²	0.41 ²
Heat of Combustion (Btu/lb).	5,070-10,810	8,410	8,660-11,660 ¹	10,660 ¹
Average Sample Thickness(feet)	1.2-6.2	2.7	7.5-36 ¹	16 ¹

¹ From Glass (1976B)

² From Glass (1975)

FIGURE 4: THE U. S. GEOLOGICAL SURVEY'S LABORATORY SEQUENCE OF SAMPLE PREPARATION AND CHEMICAL ANALYSIS FOR MAJOR AND MINOR ELEMENTS IN COAL.



By way of explanation, the following discussion of statistical methodology was provided by the U.S. Geological Survey.

In this report the geometric mean (GM) is used as the estimate of the most probable concentration (mode); the geometric mean is calculated by taking the logarithm of each analytical value, summing the logarithms, dividing the sum by the total number of values, and obtaining the antilogarithms of the result. The measure of scatter about the mode used here is the geometric deviation (GD), which is the antilog of the standard deviation of the logarithms of the analytical values. These statistics are used because the quantities of trace elements in natural materials commonly exhibit positively skewed frequency distributions; such distributions are normalized by analyzing and summarizing trace-element data on a logarithmic basis.

If the frequency distributions are lognormal, the geometric mean is the best estimate of the mode, and the

estimated range of the central two-thirds of the observed distribution has a lower limit equal to GM/GD and an upper limit equal to $GM \cdot GD$. The estimated range of the central 95 percent of the observed distribution has a lower limit equal to $GM/(GD)^2$ and an upper limit equal to $GM \cdot (GD)^2$ (Connor and others, 1976).

Although the geometric mean is, in general, an adequate estimate of the most common analytical value, it is, nevertheless, a biased estimate of the arithmetic mean. The estimates of the arithmetic means listed in the summary tables are Sichel's t statistic (Miesch, 1967).

A common problem in statistical summaries of trace-element data arises when the element content of one or more of the samples is below the limit of analytical detection. This results in a "censored" distribution. Procedures developed by Cohen (1959) were used to compute unbiased estimates of the geometric mean, geometric deviation, and arithmetic mean where the data are censored.

The U.S. Geological Survey also determined concentrations of up to 32 different trace elements in all 18 samples. While twenty-five of these elements were identified in 525° C laboratory ash, the other seven elements were determined on whole or raw coal. Figure 5 shows the U.S. Geological Survey's sequence of sample preparation and chemical analysis for all 32 elements. In addition, 23 other elements were looked for, but not detected in the samples (Table 15).

The results of the U.S. Geological Survey's analyses are given in Table 11 as parts per million (ppm) of the ash, and in Table 12 as parts per million (ppm) on a whole-coal basis. A statistical summary of this data on a whole-coal basis is provided in Table 14.

FIGURE 5: THE U. S. GEOLOGICAL SURVEY'S LABORATORY SEQUENCE OF SAMPLE PREPARATION AND CHEMICAL ANALYSIS FOR TRACE ELEMENTS IN COAL.

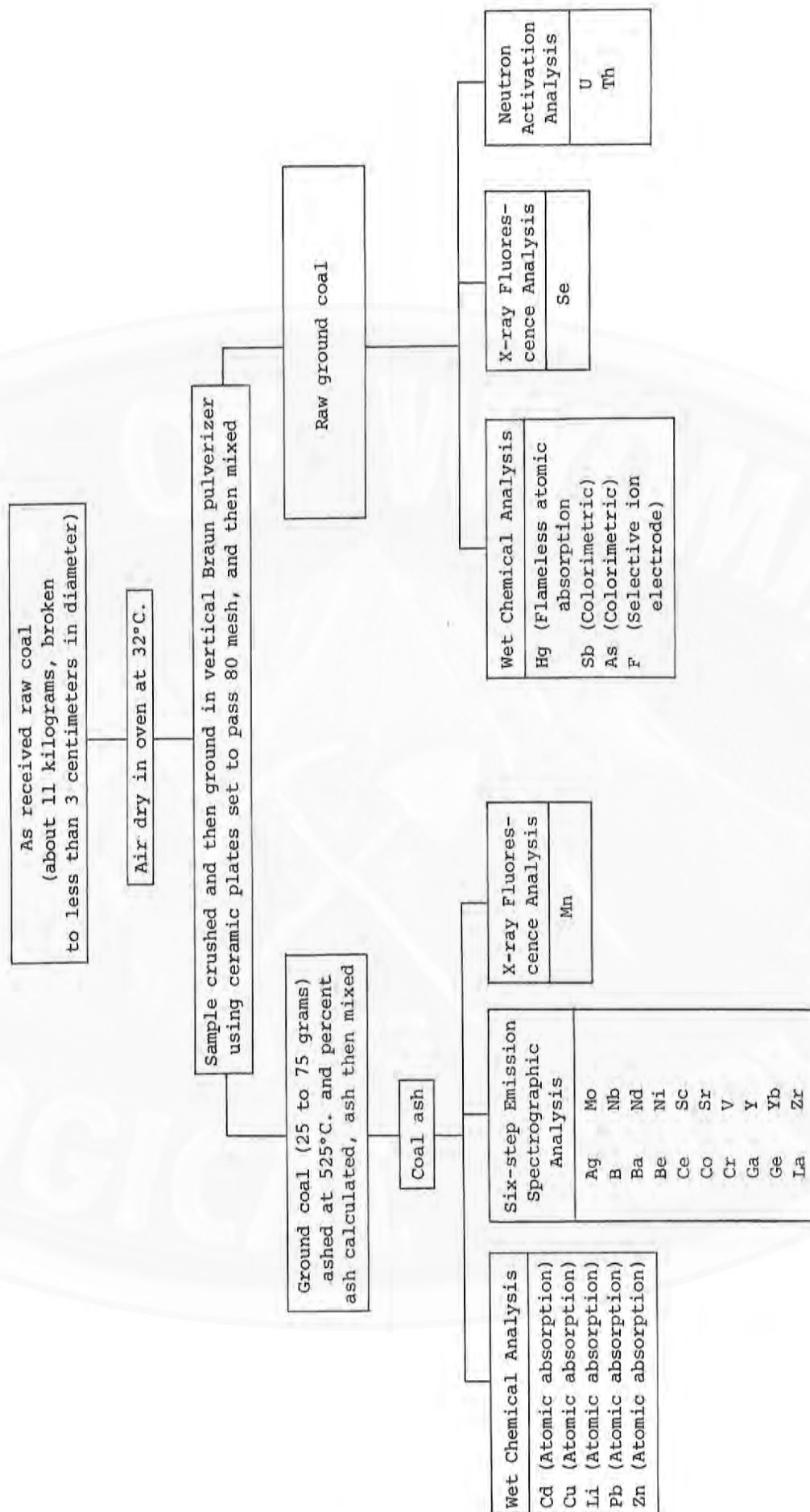


Table 11.---Major and minor oxide and trace element composition of the laboratory ash of 18 coal samples from the Carbon Basin,
Carbon County, Wyo.

[Values in percent or parts-per-million. Coal ashed at 525°C. L means less than the value shown; N, not detected; B, not determined; S after element title indicates determinations by semiquantitative emissionspectrography; to be identified with geometric brackets whose boundaries are part of the ascending series 0.12, 0.18, 0.26, 0.38, 0.56, 0.83, 1.2, etc., but reported as mid-points of the brackets, 0.1, 0.15, 0.2, 0.3, 0.5, 0.7, 1.0 etc. Precision of the spectrographic data is plus-or-minus one bracket at 68 percent or plus-or-minus two brackets at 95 percent confidence level.]

U.S.G.S. Sample number	Ash (percent)	SiO ₂ (percent)	Al ₂ O ₃ (percent)	CaO (percent)	MgO (percent)	Na ₂ O (percent)	K ₂ O (percent)	Fe ₂ O ₃ (percent)	TiO ₂ (percent)	P ₂ O ₅ (percent)	W.G.S. Sample number
D188040	23.4	50	17	7.2	1.15	0.21	1.7	14	0.88	1.0L	76-4
D188041	21.4	32	12	13	1.22	.11	1.5	29	.59	1.0L	76-5
D188042	18.3	43	13	14	1.42	.14	1.8	13	.71	1.0L	76-6
D188043	55.1	59	19	2.8	1.52	.14	2.8	9.0	.72	1.0L	76-7
D188044	45.7	45	16	2.9	1.16	.14	2.0	22	.64	1.0L	76-8
D188045	34.2	41	14	5.2	1.16	.12	1.9	30	.66	1.0L	76-9
D188046	22.5	41	16	8.9	1.27	.13	1.5	19	.78	1.0L	76-10
D188047	44.8	56	19	4.3	2.08	.17	2.5	8.0	.91	1.0L	76-11
D188048	30.6	46	17	11	1.64	.26	1.9	11	.73	1.0L	76-12
D188049	30.2	45	18	7.5	1.49	.18	1.5	17	.85	1.0L	76-13
D188050	24.8	53	18	6.6	1.51	.16	2.3	10	.81	1.0L	76-14
D188051	30.9	47	17	6.2	1.08	.17	1.8	18	.80	1.7	76-15
D188052	10.2	14	7.7	7.9	1.39	.17	.93	53	.38	1.0L	76-16
D188053	15.4	37	14	20	1.18	.16	1.3	11	.80	1.0L	76-17
D188054	37.9	52	19	4.6	1.80	.16	2.3	9.5	.73	1.0L	76-18
D188055	48.7	61	20	3.3	1.81	.16	2.4	5.2	.84	1.0L	76-19
D194472	12.8	25	12	13	1.50	.19	.69	22	.56	1.8	77-1
D194473	16.9	60	18	4.3	1.60	.24	1.6	6.7	.96	1.0L	77-2
U.S.G.S. Sample number	SO ₃ (percent)	Ag-S (ppm)	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Ce-S (ppm)	Co-S (ppm)	Cr-S (ppm)	Cu (ppm)	W.G.S. Sample number
D188040	6.2	N	150	1,000	7	2.0	200	3	20	109	76-4
D188041	8.5	N	150	500	N	2.0	N	7	15	104	76-5
D188042	7.6	N	300	1,000	2	1.0	N	3	15	80	76-6
D188043	2.3	N	100	500	3	1.0	N	10	70	54	76-7
D188044	3.1	N	70	500	3	3.0	200	20	30	121	76-8
D188045	3.7	N	100	1,500	3	2.0	N	7	30	79	76-9
D188046	5.7	N	150	1,500	3	3.0	N	10	20	121	76-10
D188047	3.5	N	150	700	3	3.0	200	10	50	100	76-11
D188048	6.2	N	150	700	2	1.0	N	7	30	68	76-12
D188049	5.4	N	150	500	3	1.0L	200	10	30	125	76-13
D188050	4.4	N	150	700	3	1.0	N	5	20	91	76-14
D188051	4.2	N	70	1,500	3	2.0	200	7	20	161	76-15
D188052	9.3	N	300	1,000	5	2.0	N	5	7	100	76-16
D188053	6.3	N	300	1,500	5	1.0L	N	5	15	107	76-17
D188054	3.7	N	150	300	3	2.0	200	7	50	105	76-18
D188055	2.1	1.5	70	500	3	2.0	N	7	50	79	76-19
D194472	14.0	N	150	2,000	N	1.0	N	30	50	105	77-1
D194473	4.6	N	150	2,000	3	2.0	L	20	100	102	77-2

Table 11.--Major and minor oxide and trace element composition of the laboratory ash of 18 coal samples from the Carbon Basin, Carbon County, Wyo.--Continued.

U.S.G.S. Sample number	Ga-S (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Nd-S (ppm)	Ni-S (ppm)	Pb (ppm)	Sc-S (ppm)	W.G.S. Sample number
D188040	30	150	36	980	15	20	150	30	30	30	76-4
D188041	20	N	34	1,330	10	N	N	50	40	10	76-5
D188042	20	N	39	840	15	20	N	50	30	15	76-6
D188043	30	100	59	440	10	20	N	30	45	15	76-7
D188044	30	150	85	600	30	20	150	150	50	15	76-8
D188045	20	100	62	635	15	20	N	70	25	15	76-9
D188046	30	100	69	1,810	15	20	N	70	50	30	76-10
D188047	30	100	135	625	15	20	150	30	35	30	76-11
D188048	30	100	57	190	15	20	N	30	40	20	76-12
D188049	30	150	107	340	15	20	150	70	25	30	76-13
D188050	30	100	66	645	15	20	N	50	40	20	76-14
D188051	30	150	69	445	30	20	150	70	55	20	76-15
D188052	30	N	28	915	30	20	N	70	30	15	76-16
D188053	30	100	41	1,560	15	20	N	70	25	20	76-17
D188054	30	150	129	560	15	20	150	30	35	30	76-18
D188055	30	100	104	230	10	20	N	30	40	15	76-19
D194472	20	N	27	1,510	20	N	B	70	45	20	77-1
D194473	30	100	72	450	15	20	150	50	25L	30	77-2
U.S.G.S. Sample number	Sr-S (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)	W.G.S. Sample number				
D188040	500	200	100	7	281	150	76-4				
D188041	300	70	70	7	224	70	76-5				
D188042	700	150	70	7	130	100	76-6				
D188043	300	150	70	7	231	200	76-7				
D188044	300	300	70	7	272	100	76-8				
D188045	300	150	70	7	210	100	76-9				
D188046	700	150	70	7	256	100	76-10				
D188047	700	300	70	7	311	100	76-11				
D188048	700	150	70	7	206	100	76-12				
D188049	500	200	70	7	324	150	76-13				
D188050	700	150	50	7	161	70	76-14				
D188051	1,500	300	100	7	185	150	76-15				
D188052	300	100	100	10	330	30	76-16				
D188053	1,000	150	70	7	171	150	76-17				
D188054	500	300	70	7	316	70	76-18				
D188055	300	150	50	7	197	50	76-19				
D194472	2,000	150	50	B	201	70	77-1				
D194473	700	200	50	7	197	150	77-2				

Table 12.--Major, minor, and trace element composition of 18 coal samples from the Carbon Basin, Carbon County, Wyo.

[Values in percent or parts-per-million. As, F, Hg, Sb, Se, Th, U, values are from direct determinations on air dried (32°C) coal; all other values calculated from analyses of ash. S means analysis by emissionspectrography; L, less than the value shown; N, not detected; B, not determined.]

U.S.G.S. Sample number	Si (percent)	Al (percent)	Ca (percent)	Mg (percent)	Na (percent)	K (percent)	Fe (percent)	Ti (percent)	Ag-S (ppm)	As (ppm)	W.G.S. Sample number
D188040	5.5	2.1	1.2	0.16	0.036	0.33	2.3	0.12	N	13	76-4
D188041	3.2	1.4	2.0	.16	.017	.27	4.3	.076	N	23	76-5
D188042	3.7	1.3	1.8	.16	.019	.27	1.7	.078	N	18	76-6
D188043	15	5.5	1.1	.50	.057	1.3	3.5	.24	N	24	76-7
D188044	9.6	3.9	.95	.32	.047	.76	7.0	.18	N	86	76-8
D188045	6.5	2.5	1.3	.24	.030	.54	7.2	.14	N	44	76-9
D188046	4.3	1.9	1.4	.17	.022	.28	3.0	.11	N	33	76-10
D188047	12	4.5	1.4	.56	.056	.93	2.5	.24	N	10	76-11
D188048	6.6	2.8	2.4	.30	.059	.48	2.4	.13	N	12	76-12
D188049	6.3	2.9	1.6	.27	.040	.38	3.6	.15	N	36	76-13
D188050	6.1	2.4	1.2	.23	.029	.48	1.7	.12	N	19	76-14
D188051	6.8	2.8	1.4	.20	.039	.46	3.9	.15	N	28	76-15
D188052	.67	.42	.58	.085	.013	.079	3.8	.023	N	31	76-16
D188053	2.7	1.1	2.2	.11	.018	.17	1.2	.074	N	B	76-17
D188054	9.2	3.8	1.2	.41	.045	.73	2.5	.17	N	20	76-18
D188055	14	5.2	1.1	.53	.058	.97	1.8	.25	.7	7	76-19
D194472	1.5	.97	1.1	.11	.018	.073	1.9	.043	N	16	77-1
D194473	4.7	1.9	.52	.16	.030	.22	.79	.097	N	9	77-2

U.S.G.S. Sample number	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Ce-S (ppm)	Co-S (ppm)	Cr-S (ppm)	Cu (ppm)	F (ppm)	Ga-S (ppm)	W.G.S. Sample number
D188040	30	200	1.5	0.47	50	0.7	5	26	110	7	76-4
D188041	30	100	N	.43	N	1.5	3	22	105	5	76-5
D188042	50	200	.3	.18	N	.5	3	15	100	3	76-6
D188043	50	300	1.5	.55	N	7	30	30	490	15	76-7
D188044	30	200	1.5	1.4	100	10	15	55	250	15	76-8
D188045	30	500	1	.68	N	3	10	27	145	7	76-9
D188046	30	300	.7	.67	N	2	5	27	115	7	76-10
D188047	70	300	1.5	1.3	100	5	20	45	295	15	76-11
D188048	200	200	.7	.31	N	2	10	21	225	10	76-12
D188049	50	150	1	.30L	70	3	10	38	215	10	76-13
D188050	30	150	.7	.25	N	1	7	23	230	7	76-14
D188051	20	500	1	.62	70	2	7	50	500	10	76-15
D188052	30	100	.7	.20	N	.5	.7	10	90	3	76-16
D188053	50	200	.7	.15L	N	.7	2	16	120	5	76-17
D188054	70	100	1	.76	70	3	15	40	265	10	76-18
D188055	30	200	1.5	.97	N	3	20	38	320	15	76-19
D194472	20	200	N	.15	N	5	7	13	75	2	77-1
D194473	20	300	.5	.30	L	3	15	17	170	5	77-2

Table 12.--Major, minor, and trace element composition of 18 coal samples from the Carbon Basin, Carbon County, Wyo.--Continued

U.S.G.S. Sample number	Hg (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Nd-S (ppm)	Ni-S (ppm)	P (ppm)	Pb (ppm)	W.G.S. Sample number	
D188040	0.14	30	8.4	230	3	5	30	7	1,000L	7.0	76-4	
D188041	.20	N	7.3	280	2	N	N	10	940L	8.6	76-5	
D188042	.15	N	7.1	150	3	3	N	10	800L	5.5	76-6	
D188043	.24	50	33	240	5	10	N	15	2,400L	25	76-7	
D188044	.18	70	39	270	15	10	70	70	2,000L	23	76-8	
D188045	.22	30	21	220	5	7	N	20	1,500L	8.5	76-9	
D188046	.36	20	16	410	3	5	N	15	980L	11	76-10	
D188047	.25	50	60	280	7	10	70	15	2,000L	16	76-11	
D188048	.10	30	17	58	5	7	N	10	1,300L	12	76-12	
D188049	.35	50	32	100	5	7	50	20	1,300L	7.6	76-13	
D188050	.20	20	16	160	3	5	N	15	1,100L	9.9	76-14	
D188051	.16	50	21	140	10	7	50	20	2,300	17	76-15	
D188052	.22	N	2.9	93	3	2	N	7	450L	3.1	76-16	
D188053	.17	15	6.3	240	2	3	N	10	670L	3.8	76-17	
D188054	.18	70	49	210	7	7	70	10	1,700L	13	76-18	
D188055	.12	50	51	110	5	10	N	15	2,100L	19	76-19	
D194472	.12	N	3.4	190	2	N	B	10	1,000	5.7	77-1	
D194473	.29	15	12	76	2	3	20	10	730L	4.2L	77-2	
U.S.G.S. Sample number	Sb (ppm)	Sc-S (ppm)	Se (ppm)	Sr-S (ppm)	Th (ppm)	U (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)	W.G.S. Sample number
D188040	0.8	7	2.2	100	5.4	4.2	50	20	1.5	66	30	76-4
D188041	.8	2	2.9	70	4.3	3.8	15	15	1.5	48	15	76-5
D188042	.8	3	1.9	150	4.0	5.6	30	15	1.5	24	20	76-6
D188043	1.6	10	3.1	150	11.9	6.7	100	50	5	130	100	76-7
D188044	4.0	7	5.1	150	12.7	15	150	30	3	120	50	76-8
D188045	1.3	5	3.7	100	7.3	5.5	50	20	2	72	30	76-9
D188046	1.4	7	4.6	150	7.0	3.8	30	15	1.5	58	20	76-10
D188047	1.2	15	3.6	300	8.8	5.1	150	30	3	140	50	76-11
D188048	1.0	7	2.5	200	6.2	4.2	50	20	2	63	30	76-12
D188049	1.2	10	4.4	150	7.3	3.8	70	20	2	98	50	76-13
D188050	.8	5	2.9	150	6.4	3.8	30	15	1.5	40	20	76-14
D188051	2.9	7	4.8	500	11.8	17	100	30	2	57	50	76-15
D188052	.8	1.5	2.8	30	1.9	2.3	10	10	1	34	3	76-16
D188053	.8	3	2.7	150	3.9	2.6	20	10	1	26	20	76-17
D188054	1.7	10	3.3	200	8.2	5.2	100	30	3	120	30	76-18
D188055	1.3	7	2.9	150	10.0	4.8	70	20	3	96	20	76-19
D194472	.8	2	1.5	200	1.8	2.5	20	7	B	25	10	77-1
D194473	6.0	5	2.6	100	6.0	4.0	30	10	1	33	20	77-2

Table 13.--Arithmetic mean, observed range, geometric mean, and geometric deviation of ash content and contents of nine major and minor oxides in the laboratory ash of 16 Carbon Basin, Carbon County, Wyoming coal samples.¹ For comparison, geometric means of analyses for 295 Rocky Mountain Province coal samples (Hatch and Swanson, 1977, table 3a) are included.

[All samples were ashed at 525°C. All values are in percent]

Oxide or element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Rocky Mtn. Province geometric mean
		minimum	maximum			
Ash	31.3	10.2	55.1	28.2	1.6	10.9
SiO ₂	46	14	61	43	1.4	44
Al ₂ O ₃	16	7.7	20	16	1.3	19
CaO	7.9	2.8	20	6.7	1.8	6.2
MgO	1.43	1.08	2.08	1.40	1.2	1.4
Na ₂ O	.16	.11	.26	.16	1.2	.68
K ₂ O	1.9	.93	2.8	1.8	1.3	.45
Fe ₂ O ₃	17	5.2	53	15	1.8	4.5
TiO ₂	.74	.38	.91	.73	1.2	.81
SO ₃	5.2	2.1	9.3	4.7	1.6	5.1

¹ Does not include data for samples 77-1 and 77-2

Table 14.--Arithmetic mean, observed range, geometric mean and geometric deviation of 37 elements in 16 Carbon Basin, Carbon County, Wyoming coal samples¹(whole coal basis). For comparison, geometric means of analyses for 295 Rocky Mountain Province coal samples (Hatch & Swanson, 1977, table 36) are included.

[As, F, Hg, Sb, Se, Th, and U values used to calculate the statistics were determined directly on whole coal. All other values used were calculated from determinations made on coal ash. L, less than the value shown. Leaders (---) indicate no data available]

Element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Rocky Mtn. Province
		Minimum	Maximum			geometric mean
Percent						
Si	7.6	0.67	15	5.7	2.1	2.3
Al	2.9	.42	5.5	2.3	1.9	1.1
Ca	1.4	.58	2.4	1.4	1.4	.48
Mg	.28	.085	.56	.24	1.7	.089
Na	.037	.013	.059	.033	1.6	.055
K	.55	.079	1.3	.43	2.0	.041
Fe	3.3	1.2	7.2	2.9	1.6	.34
Ti	.15	.023	.25	.12	1.8	.047
Parts per million						
As	27	6.7	86	22	1.9	2
B	50	20	70	50	1.4	70
Ba	200	100	500	200	1.7	150
Be	1	.3L	1.5	1	1.7	.5
Cd	.6	.2L	1.4	.4	2.2	.05
Co	3	.5	10	2	2.5	1.5
Cr	10	.7	30	7	2.7	5
Cu	31	10	55	27	1.6	8.4
F	225	90	500	192	1.8	69
Ga	10	3	15	7	1.7	3
Hg	.20	.1	.36	.19	1.4	.05
La	30	15L	70	30	2.0	---
Li	26	2.9	60	18	2.4	8.0
Mn	200	58	410	180	1.7	20
Mo	5	2	15	5	1.7	1.5
Nb	7	2	10	5	1.8	.5
Ni	15	7	70	15	1.7	2
Pb	12	3.1	25	10	1.8	4.7
Sb	1.4	.8	4.0	1.2	1.6	.3
Sc	7	1.5	15	7	1.9	1.5
Se	3.3	1.9	5.1	3.2	1.3	1.2
Sr	150	30	500	150	1.8	100
Th	7.5	1.9	12.7	6.6	1.6	2.9
U	5.7	2.3	17.1	5.0	1.7	1.1
V	70	10	150	50	2.2	100
Y	20	10	50	20	1.5	5
Yb	2	1	5	2	1.5	.5
Zn	76	24	140	65	1.8	6.8
Zr	80	3	100	30	2.2	20

¹Does not include data for samples 77-1 and 77-2

Table 15. Elements looked for, but not detected in 18 coal samples from the Carbon Basin of southcentral Wyoming.

(Approximate lower detection limits for these elements in coal ash, by the six-step spectrographic method of the U.S. Geological Survey, are included)

Element Name	Symbol	Lower limit of detection (ppm) in coal ash
Gold	Au	50
Bismuth	Bi	20
Dysprosium	Dy	100
Erbium	Er	100
Europium	Eu	200
Gadolinium	Gd	100
Germanium	Ge	20
Hafnium	Hf	200
Holmium	Ho	50
Indium	In	20
Lutetium	Lu	70
Palladium	Pd	5
Praseodymium	Pr	200
Platinum	Pt	100
Rhenium	Re	100
Samarium	Sm	200
Tin	Sn	20
Tantalum	Ta	1,000
Terbium	Tb	700
Tellurium	Te	5,000
Thallium	Tl	100
Thulium	Tm	50
Tungsten	W	200

REFERENCES

- American Society for Testing Materials, 1974, Annual book of ASTM standards, Part 26, Gaseous fuels; coal and coke; atmospheric analysis: Philadelphia, Pennsylvania, 828 p.
- Cohen, A.C., 1959, Simplified estimators for the normal distribution when samples are singly censored or truncated: *Technometrics*, v.1, no.3, p.217-237.
- Connor, J.J., Keith, J.R., and Anderson, B.M., 1976, Trace-metal variation in soils and sagebrush in the Powder River Basin, Wyoming and Montana: *U.S. Geological Survey Journal of Research*, v.4, no.1, p.49-59.
- Dobbin, C.E., Bowen, C.F., and Hoots, H.W., 1929, Geology and coal and oil resources of the Hanna and Carbon basins, Carbon County, Wyoming: *U.S. Geological Survey Bulletin* 804, 88 p.
- Gill, J.R., Merewether, E.A., and Cobban, W.A., 1970, Stratigraphy and nomenclature of some upper Cretaceous and lower Tertiary rocks in southcentral Wyoming: *U.S. Geological Survey Professional Paper* 667, 50 p.
- Glass, G.B., 1972, Mining in the Hanna Coal Field: *Geological Survey of Wyoming Miscellaneous Report*, 45 p.
- Glass, G.B., 1975, Analyses and measured sections of 54 Wyoming coal samples (collected in 1974): *Geological Survey of Wyoming Report of Investigations No.11*, 219 p.
- Glass, G.B., 1976A, Geophysical logs of three core holes drilled in the Carbon Basin of southcentral Wyoming: *Geological Survey of Wyoming Open File Report WGS 76-1*, 3 p.
- Glass, G.B., 1976B, Review of Wyoming Coalfields, 1976: *Geological Survey of Wyoming Public Information Circular* 4, 21 p.
- Hatch, J.R., and Swanson, V.E., 1977, Trace elements in Rocky Mountain coals, in *Geology of Rocky Mountain coal--a symposium*: *Colorado Geological Survey Resources Series* 1, p. 143-165.

- Hettinger, R.D., 1978, Lithologic and geophysical logs of 24 coal test holes drilled during 1977 in the Carbon Basin, Carbon County, Wyoming: U.S. Geological Survey Open-File Report 78-702, 78 p.
- Hyden, H.J., and McAndrews, H., 1967, Geologic map of the TL Ranch Quadrangle: U.S. Geological Survey Map GQ-637.
- Miesch, A.T., 1967, Methods of computation for estimating geochemical abundances: U.S. Geological Survey Professional Paper 574-B, 15 p.
- Office of Coal Research, 1967, Methods of analyzing and testing coal and coke: U.S. Bureau of Mines Bulletin 638, 85 p.
- Schopf, J.M., 1960, Field description and sampling of coal beds: U.S. Geological Survey Bulletin 1111-B, 70 p.
- Swanson, V.E., and Huffman, Claude, Jr., 1975, Guidelines for sample collecting and analytical methods used in the U.S. Geological Survey for determining chemical composition of coal: U.S. Geological Survey unpublished report, Denver, Colorado, 35 p.

APPENDIX A

LITHOLOGIC DESCRIPTIONS OF 5 CORE HOLES
AND 2 DRILL HOLES DRILLED IN THE
CARBON BASIN

CORE HOLE WGS-C1

Location: 250 feet north and 1,450 feet west from the SE corner of Section 34, T.22N., R.80W.



STATE: Wyoming
 COUNTY: Carbon
 QUADRANGLE: Carbon
 COAL-BEARING AREA: Hanna
 COAL FIELD: Hanna

DATE OF COMPLETION: 10/24/76
 TOTAL DEPTH: 507.7 feet
 SURFACE ELEVATION: 7040
 LOGGED BY: Gary B. Glass
 STRIKE: 13°
 DIP: less than 15° SE

GEOLOGIC FORMATION: Hanna
 AGE: Paleocene

SHEET 1 OF 5

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
0	25.0	SAND, dusky yellow (5Y6/4); fine to medium grained; (air-drilled cuttings)
25.0	5.0	SANDSTONE AND CLAY SHALE, dusky yellow (5Y6/4) sand and light olive gray (5Y5/2) shale; sand very fine to fine grained; (air-drilled cuttings)
30.0	1.0	SANDSTONE, very light gray (N8); fine grained; calcareous; sharp basal contact
31.0	25.8	SANDSTONE, yellowish gray (5Y7/2); fine grained to pebbly, shale chips and fragments common; two fining upward units, 5 and 12 feet thick; cross-bedded; twigs
56.8	0.7	CORE LOSS
57.5	1.4	SILT SHALE, light gray (N7); sandy zones; plant debris; sharp basal contact
58.9	68.8	SANDSTONE, yellowish gray (5Y5/2) near top to very light gray (N8) downward; fine to very coarse grained; six fining upward units, 5-25 feet thick; cross-bedded; twigs, bark, and plant debris; unconformable basal contact
127.7	6.1	SILTSTONE, medium light gray (N6); sandy laminae; plant debris; sharp basal contact
133.8	25.2	SANDSTONE, light gray (N7) to very light gray (N8); fine to coarse grained; 6 fining upward units, 3-6 feet thick; upper 5 feet calcareous; cross-bedded; twigs and coalified debris; unconformable basal contact
159.0	1.2	COAL, Sample No. 76-4; Carbon No. 6 Rider coal bed; sharp basal contact
160.2	4.1	CLAY SHALE, medium light gray (N6); upper 0.7 feet grayish black (N2) with coal laminae; leaves, twigs, reeds, grass; sharp basal contact

CORE HOLE WGS-C1, CONTINUED

SHEET 2 OF 5

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
164.3	1.8	COAL, Sample No. 76-5; Carbon No. 6 Rider coal bed; sharp basal contact
166.1	2.9	CLAY SHALE, medium gray (N5) to medium light gray (N6); reeds and grass
169.0	5.5	CORE LOSS
174.5	7.1	CLAYSTONE, medium gray (N5); rootlets; sharp basal contact
181.6	4.7	SANDSTONE, light gray (N7) to very light gray (N8); silty to fine grained; ripplemarked; rootlets at top; sharp basal contact
186.3	4.2	INTERBEDDED CLAY SHALE AND SANDSTONE, medium light gray (N6) shale and light gray (N7) sand; silty to fine grained sand units 0.3-0.7 feet thick; shale units 1-2 feet thick; rootlets, twigs, and reeds; sharp basal contact
190.5	7.2	CLAYSTONE, medium dark gray (N4) to medium gray (N5); rootlets, twigs, and reeds; gradational basal con- tact
197.7	17.0	SAND-CLAY LAMINITE, medium gray (N5) clay and light gray (N7) sand; silt to very fine sand, 2 feet bedded at top to thin interbeds and laminae near base; burrowed; twigs, leaves, and plant debris; sharp basal contact
214.7	2.3	COAL, Sample No. 76-6; Upper Carbon No. 6 coal bed; sharp basal contact
217.0	2.0	CLAY SHALE, grayish black (N2) to dark gray (N3); coal laminae
219.0	0.5	CORE LOSS
219.5	0.8	CLAYSTONE, olive black (5Y2/1); rootlets; sharp basal contact
220.3	1.6	COAL, Sample No. 76-7; Lower Carbon No. 6 coal bed; sharp basal contact
221.9	4.1	SAND-CLAY LAMINITE, light gray (N7) sand and medium gray (N5) clay; very fine grained sand laminae in- crease downward; brecciated appearance at top; burrowed in lower half; gradational basal contact
226.0	8.6	INTERBEDDED CLAYSTONE AND SILTSTONE, medium dark gray (N4) clay and medium gray (N5) silt; 0.4-2.3 feet interbeds; 0.2 feet <u>coal</u> interbed at 231.4-232.2 feet; rootlets

CORE HOLE WGS-C1, CONTINUEDSHEET 3 OF 5

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
234.6	1.4	CORE LOSS
236.0	3.5	CLAYSTONE, medium dark gray (N4); sharp basal contact
239.5	12.0	SILTSTONE, medium gray (N5) silt with light gray (N7) sand laminae; sand silty to very fine grained; ripplemarked; rootworked; leaves, reeds, and plant debris; sharp basal contact
251.5	7.7	SAND-SILT LAMINITE, light gray (N7) sand and medium gray (N5) silt; sand units thicken to 2 feet in places; ripplemarks; leaves and plant debris; gradational basal contact
259.2	7.6	SANDSTONE, light gray (N7) with medium gray (N5) silt laminae; silty to very fine grained; calcareous in places; rootworked?; leaves; sharp basal contact
266.8	3.1	INTERBEDDED SILTSTONE AND CLAYSTONE, medium light gray (N6) to greenish gray (5G6/1); grass and leaves; sharp basal contact
269.9	3.9	CLAY SHALE, dark gray (N3); coal laminae; plant debris; sharp basal contact
273.9	1.65	<u>COAL</u> , Sample No. 76-8; Upper Carbon No. 7 (upper bench) coal bed; shaly in places; sharp basal contact
275.55	0.35	CLAY SHALE, grayish black (N2); coal laminae; plant debris; sharp basal contact
275.9	1.9	<u>COAL</u> , Sample No. 76-9; Upper Carbon No. 7 (lower bench) coal bed; shaly in places; sharp basal contact
277.8	3.3	CLAYSTONE, medium gray (N5); upper 1.2' mottled medium dark gray (N4) and light olive gray (5Y6/1); rootlets
281.1	4.7	CORE LOSS
285.8	8.5	CLAY SHALE, medium dark gray (N4) grading down into grayish black (N2); burrowed; reeds, leaves, and plant debris; sharp basal contact
294.3	1.3	<u>COAL</u> , Sample No. 76-10; Lower Carbon No. 7 coal bed; sharp basal contact
295.6	7.6	CLAYSTONE, medium light gray (N6) to light olive gray (5Y6/1); rootlets; plastic; gradational basal contact

CORE HOLE WGS-C1, CONTINUEDSHEET 4 OF 5

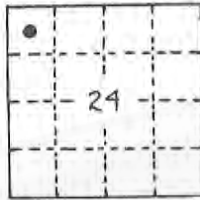
DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
303.2	6.7	CLAY SHALE, medium gray (N5) to olive gray (5Y4/1); rootlets at top; leaves, twigs, and plant debris; sandstone laminae and interbeds at base
309.9	14.4	SANDSTONE, light gray (N7); silty to medium grained; ripplemarked and cross-bedded; calcareous near base
324.3	2.7	CORE LOSS
327.0	11.3	SANDSTONE, light gray (N7) to very light gray (N8); fine to medium grained; cross-bedded; calcareous; plant debris
338.3	8.9	CORE LOSS
347.2	8.7	SANDSTONE, light gray (N7) to very light gray (N8); medium to coarse grained; cross-bedded; shale chips common; calcareous
355.9	1.3	CORE LOSS
357.2	0.2	SANDSTONE, light gray (N7) to very light gray (N8); fine to coarse grained; calcareous
357.4	1.7	CORE LOSS
359.1	1.3	SHALE-PEBBLE CONGLOMERATE, medium gray (N5) shale in a light gray (N7) sand matrix; fine to medium grained sand with shale pebbles to 2 inches in diameter; fining upward unit; calcareous; sharp basal contact
360.4	74.8	SANDSTONE, light gray (N7); fine to very coarse grained; at least four fining upward units noted, 5-15 feet thick; medium gray (N5) shale chips common at the base of some units; calcareous in places; coalified bark
435.2	2.4	CORE LOSS
437.6	49.1	SANDSTONE, light gray (N7); fine to very coarse grained; three fining upward units, 5-15 feet thick; medium gray (N5) shale-pebbles and chips at the base of some units; calcareous in places; cross-bedded in places; bark and plant debris
467.2	0.5	CORE LOSS
467.7	9.3	SANDSTONE, light gray (N7); fine grained to granular; includes parts of two fining upward units, 7-19 feet thick; medium gray (N5) shale-pebbles in upper 1.8 feet; calcareous in places; cross-bedded in places; plant debris

CORE HOLE WGS-C1, CONTINUEDSHEET 5 OF 5

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
476.5	0.8	CORE LOSS
477.7	9.0	SANDSTONE, light gray (N7); very fine to very coarse grained; portion of fining upward unit; cross-bedded and ripplemarked; plant debris
486.7	1.0	CORE LOSS
487.7	1.0	SANDSTONE, light gray (N7); coarse to very coarse grained with shale and coal pebbles common; sharp basal contact
488.7	4.3	<u>COAL</u> , Sample No. 76-11; Bed No. 111 coal; estimate up to 1.5 feet lost in coring; sharp basal contact
493.0	1.6	CLAY SHALE, medium light gray (N6); rootlets; sharp basal contact
494.6	0.1	<u>COAL</u> , not samples; unnamed; sharp basal contact
494.7	1.9	SILTSTONE, medium light gray (N6); rootlets; gradational basal contact
496.6	3.4	SAND-SILT LAMINITE, light gray (N7) sand with medium light gray (N6) silt laminae and interbeds; silty to very fine grained sand; ripplemarked; rootlets, reeds, and twigs
500.0	7.7	CORE LOSS
507.7		
		TOTAL CORE LOSS 40.9 feet
		OVERALL RECOVERY 92%

CORE HOLE WGS-C2

Location: 650 feet south and 850 feet east from the NW corner of Section 24, T.21N., R.80W.



STATE: Wyoming
 COUNTY: Carbon
 QUADRANGLE: Halfway Hill
 COAL-BEARING AREA: Hanna
 COAL FIELD: Hanna

DATE OF COMPLETION: 12/7/76
 TOTAL DEPTH: 414.4 feet
 SURFACE ELEVATION: 7150
 LOGGED BY: Gary B. Glass
 STRIKE: 90°
 DIP: 2-3° N

GEOLOGIC FORMATION: Hanna
 AGE: Paleocene

SHEET 1 OF 5

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
0	49.0	SAND, loose; no recovery or description
49.0	2.0	CLAYSTONE, medium gray (N5); air-drilled cuttings
51.0	5.7	CLAY SHALE, medium dark gray (N4) to medium light gray (N6); plant debris; gradational basal contact
56.7	1.3	SILTSTONE, medium light gray (N6); calcareous; rootlets; gradational basal contact
58.0	3.3	CLAY SHALE, medium gray (N5) to medium light gray (N6); twigs and grass; gradational basal contact
61.3	3.4	CLAYSTONE, medium gray (N5); loose and jumbled in core barrel
64.7	5.9	CORE LOSS
70.6	0.3	SHALY COAL, not sampled; Bed No. 110 coal; sharp basal contact
70.9	3.7	CLAYSTONE INTERBEDDED WITH INTERLAMINATED CLAY SHALE AND COAL, medium gray (N5) claystone and grayish black (N2) clay shale; 0.2-1.6 feet thick interbeds; coal makes up less than 20% of the interlaminated units
74.6	2.4	CORE LOSS
77.0	1.6	CLAY SHALE, dark gray (N3); shaly coal to interlaminated clay shale and coal at about middle of unit; gradational basal contact
78.6	2.4	CLAYSTONE, dark gray (N3); loose and jumbled in core barrel; rootlets near base; gradational basal contact
81.0	2.0	SAND-SILT-CLAY LAMINITE, light gray (N7) sand, medium gray (N5) silt, and medium dark gray (N4) clay; sandy laminae at top only; burrowed; rootlets and leaves; gradational basal contact

CORE HOLE WGS-C2, CONTINUEDSHEET 2 OF 5

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
83.0	2.9	CLAY SHALE, medium gray (N5) to grayish black (N2) downward; coal laminae near base; rootlets, grass, reeds, and plant debris; gradational basal contact
85.9	2.8	CLAYSTONE, medium gray (N5); rootlets; gradational basal contact
88.7	12.2	CLAY SHALE, medium gray (N5) to medium dark gray (N4) downward; leaves, grass, reeds, and rootlets; sharp basal contact
100.9	7.2	<u>COAL</u> , Sample No. 76-12; Upper Bed No. 109 coal; upper 1.4 feet of shaly coal and clay shale not included in sample; sharp basal contact
108.1	0.9	CLAYSTONE, grayish black (N2) to dark gray (N3); coal laminae; sharp basal contact
109.0	1.95	<u>COAL</u> , Sample No. 76-13; Lower Bed No. 109 coal; sharp basal contact
110.95	0.25	CLAY SHALE, dark gray (N3); coal laminae; plant debris; sharp basal contact
111.2	19.8	INTERBEDDED SANDSTONE, SILTSTONE, AND CLAYSTONE, light gray (N7) to very light gray (N8) sand, medium gray (N5) to medium light gray (N6) silt, and medium gray (N5) clay; ½ inch to 2 feet thick interbeds with a few laminite zones; leaves, rootlets, grass, reeds, and plant debris; gradational basal contact
131.0	27.4	SANDSTONE, light gray (N7) to very light gray (N8); very fine to coarse grained; two fining upward units, 12 and 15 feet thick; medium gray (N5) siltstone interbeds and fragments noted; cross-bedded; bark; sharp basal contact
158.4	2.0	CLAYSTONE, mottled medium dark gray (N4) to medium light gray (N6); brecciated appearance; rootlets; sharp basal contact
160.4	0.6	SHALE-PEBBLE CONGLOMERATE, greenish gray (5G6/1) shale in a very light gray (N8) sand matrix; very fine to fine grained sand with shale-pebbles; slightly calcareous; sharp basal contact
161.0	3.8	SILTSTONE, medium gray (N5); light gray (N7) to very light gray (N8) sand laminae common at top; root-worked; leaves and plant debris; sharp basal contact

CORE HOLE WGS-C2, CONTINUEDSHEET 3 OF 5

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
164.8		INTERBEDDED SANDSTONE AND SILTSTONE, light gray (N7) to very light gray (N8) sand and medium gray (N5) silt; silty to fine grained sand; 2 inches-2 feet thick interbeds; part of a fining upward unit; few shale-pebble zones; ripplemarked; calcareous in places; sharp basal contact
	9.3	
174.1		SANDSTONE, very light gray (N8); fine to coarse grained sand with medium gray (N5) siltstone fragments in 0.5-0.8 feet thick units in lower 4 feet; calcareous in places; part of a fining upward unit; gradational basal contact
	26.9	
191.0		SANDSTONE, light gray (N7); medium grained to granular; fining upward unit; cross-bedded; calcareous in places
	20.0	
211.0	2.5	CORE LOSS
213.5		SANDSTONE, light gray (N7); fine grained to granular sand with medium light gray (N6) silt and clay shale-pebble zones; six fining upward units, 2.5-18 feet thick; cross-bedded in places; calcareous in places; coalified bark; sharp basal contact
	56.2	
269.7		CLAY SHALE, medium light gray (N6) to dark gray (N3) downward; basal 0.1 feet is coal; plant debris, reeds and grass; sharp basal contact
	1.4	
271.1		CLAY SHALE, dark gray (N3) to medium dark gray (N4); freshwater gastropods; plant debris and reeds; gradational basal contact
	1.8	
272.9		CLAYSTONE, dark gray (N3) to brownish gray (5YR4/1); grass, reeds, leaves, and rootlets; shaly in places with coal laminae; gradational basal contact
	3.1	
276.0		<u>SHALY COAL</u> , not sampled; Bed No. 108 coal; sharp basal contact
	1.2	
277.2		INTERBEDDED CLAYSTONE AND CLAY SHALE, olive gray (5Y4/1) claystone and dark gray (N3) to medium gray (N5) clay shale, 0.2-2.8 feet thick interbeds; some coal laminae; reeds, grass, and rootlets; gradational basal contact
	7.4	
284.6		SANDSTONE, very light gray (N8), silty to very fine grained; ripplemarked; calcareous in upper half; unconformable basal contact
	4.6	

CORE HOLE WGS-C2, CONTINUEDSHEET 4 OF 5

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
289.2		INTERBEDDED SANDSTONE AND SILT-CLAY LAMINITE, light gray (N7) to very light gray (N8) sand, medium gray (N5) to medium light gray (N6) silt, and medium dark gray (N4) to medium gray (N5) clay; very fine grained sand; 0.2-0.9 feet thick interbeds; ripplemarked; calcareous in places; plant debris; sharp basal contact
	3.9	
293.1		CLAY SHALE, medium light gray (N6) to dark gray (N3) downward; coal laminae at base; freshwater ostracodes; grass, reeds, and plant debris
	1.8	
294.9	0.8	CORE LOSS
295.7		CLAY SHALE, medium light gray (N6) to grayish black (N2); coal laminae at top; leaves, grass, reeds, and plant debris; gradational basal contact
	0.7	
296.4		INTERBEDDED CLAYSTONE AND CLAY SHALE, brownish gray (5YR4/1) to medium light gray (N6); gradational interbeds; rootlets; gradational basal contact
	3.9	
300.3		CLAY SHALE, medium dark gray (N4) to medium gray (N5); mud cracks; freshwater ostracodes, pelecypods, and gastropod operculae; leaves, grass, and reeds; sharp basal contact
	19.5	
319.8		SANDSTONE, light gray (N7) to very light gray (N8); silty to granular; fining upward unit; ripplemarked at top, cross-bedded below; plant debris; sharp basal contact
	9.6	
329.4		INTERBEDDED SILTSTONE AND CLAYSTONE, medium gray (N5) to greenish gray (5G6/1); gradational interbeds; unconformable basal contact
	1.2	
330.6		CLAY SHALE, medium gray (N5) and dark gray (N3) laminae (varved appearance); fish scales and bones; leaves; basal contact sharp
	7.6	
338.2		SANDSTONE, light gray (N7); very fine to very coarse grained; poorly sorted; coalified bark
	1.0	
339.2	2.3	CORE LOSS
341.5		SANDSTONE, light gray (N7) to very light gray (N8); fine grained to pebbly with 0.5-2.4 feet thick shale-pebble zones common; six fining upward units, 2.5-10 feet thick; cross-bedded; calcareous in places
	51.4	
392.9	1.0	CORE LOSS

CORE HOLE WGS-C2, CONTINUEDSHEET 5 OF 5

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
393.9	20.5	SANDSTONE, light gray (N7) to very light gray (N8); very fine to very coarse grained; three fining upward units, 5-9 feet thick; cross-bedded
414.4		
		TOTAL CORE LOSS 14.9 feet
		OVERALL RECOVERY 96%

DRILL HOLE WGS-C2A

Location: 475 feet south and 950 feet east from the NW corner of Section 24, T.21N., R.80W.



STATE: Wyoming
 COUNTY: Carbon
 QUADRANGLE: Halfway Hill
 COAL-BEARING AREA: Hanna
 COAL FIELD: Hanna

DATE OF COMPLETION: 12/9/76
 TOTAL DEPTH: 200 feet
 SURFACE ELEVATION: 7165
 LOGGED BY: Gary B. Glass
 STRIKE: 90°
 DIP: 2-3° N

GEOLOGIC FORMATION: Hanna
 AGE: Paleocene

SHEET 1 OF 1

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
0	25	SANDSTONE, grayish orange (10YR7/4); fine to coarse grained; friable; air-drilled cuttings
25	9	SANDSTONE, yellowish gray (5Y7/2); fine to very coarse grained with shale chips; air-drilled cuttings
34	9	CLAY SHALE, medium dark gray (N4); air drilled cuttings
43	1	COAL, not sampled; Bed No. 111 coal; air-drilled cuttings
44	6	CLAY SHALE, medium gray (N5); air-drilled cuttings
50	5	SILTSTONE, medium dark gray (N4); air-drilled cuttings
55	5	CLAY SHALE, medium gray (N5); silty; air-drilled cuttings
60	140	Air-drilled cuttings not described; see WGS-C2
200		

CORE HOLE WGS-C3

Location: 215 feet north and 1,275 feet west of the SE corner of Section 35, T.22N., R.80W.



STATE: Wyoming
 COUNTY: Carbon
 QUADRANGLE: Halfway Hill
 COAL-BEARING AREA: Hanna
 COAL FIELD: Hanna

DATE OF COMPLETION: 11/15/76
 TOTAL DEPTH: 620.7 feet
 SURFACE ELEVATION: 6950
 LOGGED BY: Gary B. Glass
 STRIKE:
 DIP: Horizontal

GEOLOGIC FORMATION: Hanna
 AGE: Paleocene

SHEET 1 OF 8

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
0	5.0	CLAY AND SOIL, moderate yellowish brown (10YR5/4); minor amount of sand; air-drilled cuttings
5.0	10.0	SANDSTONE, yellowish gray (5Y7/2); medium to very coarse grained; friable; air-drilled cuttings
15.0	5.0	SILT SHALE, yellowish gray (5Y7/2); air-drilled cuttings
20.0	3.0	CLAYSTONE, yellowish gray (5Y7/2); air-drilled cuttings
23.0	0.7	SILTSTONE, yellowish gray (5Y7/2); few ½-1 inch thick very fine grained sandstone interbeds; gradational basal contact
23.7	5.8	CLAYSTONE, yellowish gray (5Y7/2); shaly in places; coalified roots; plastic
29.5	1.0	CORE LOSS
30.5	6.8	CLAYSTONE, yellowish gray (5Y7/2) to pale olive (10Y6/2); shaly in places; plastic
37.3	1.5	CORE LOSS
38.8	6.8	CLAYSTONE, yellowish gray (5Y7/2) grading down into greenish gray (5GY6/1) and medium light gray (N6); silty at base; upper part jumbled and broken in core barrel; gradational basal contact
45.6	13.7	INTERBEDDED SILTSTONE AND CLAYSTONE, light bluish gray (5B7/1) to medium light gray (N6); gradational interbeds with sandy zones near base; roots near base; gradational basal contact
59.3	0.6	CLAY SHALE, medium light gray (N6); silty in places
59.9	1.6	CORE LOSS

CORE HOLE WGS-C3, CONTINUEDSHEET 2 OF 8

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
45.6		INTERBEDDED SILTSTONE AND CLAYSTONE, light bluish gray (5B7/1) to medium light gray (N6); gradational interbeds with sandy zones near base; roots near base; gradational basal contact
	13.7	
59.3	0.6	CLAY SHALE, medium light gray (N6); silty in places
59.9	1.6	CORE LOSS
60.5		INTERBEDDED CLAYSTONE AND CLAY SHALE, medium light gray (N6) with occasional very fine grained, light gray (N7) sandstone interbeds, 0.2-0.5 feet thick; some claystones exhibit brecciated appearance; burrowed; roots in lower 4 feet; gradational basal contact
	16.7	
77.2		SANDSTONE, light gray (N7); very fine to coarse grained; fining upward unit; cross-bedded
	1.7	
78.9	11.0	CORE LOSS
89.9		SANDSTONE, light gray (N7); fine to medium grained; calcareous
	0.6	
90.5	22.0	CORE LOSS
112.5		SANDSTONE, light gray (N7); medium grained to granular with medium light gray shale-pebble zones common; three fining upward units, 4-10 feet thick; cross-bedded; calcareous in places; coalified bark
	19.5	
132.0	9.0	CORE LOSS
141.0		SANDSTONE, light gray (N7); coarse grained to pebbly; fining upward unit; some shale-pebbles at base; unconformable basal contact
	4.1	
145.1		SANDSTONE, light gray (N7); very fine to fine grained; medium light gray (N6) silt laminae at top; ripple-marked; rootlets
	1.4	
146.5	5.3	CORE LOSS, may include a Carbon No. 6 Rider coal bed
151.8		INTERLAMINATED CLAY SHALE AND COAL, grayish black (N2) to dark gray (N3) shale; coal laminae make up less than 25% of unit; leaves
	0.7	
152.5	2.0	CORE LOSS
154.5		CLAY SHALE, olive black (5Y2/1) to grayish black (N2); coal laminae; rootlets and plant debris; gradational basal contact

CORE HOLE WGS-C3, CONTINUEDSHEET 3 OF 8

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
155.3	0.4	<u>SHALY COAL</u> , not sampled; Carbon No. 6 Rider coal bed; sharp basal contact
155.7	1.0	CLAYSTONE, mottled brownish gray (5YR4/1) and brownish black (5YR2/1); brecciated appearance; upper 0.4 feet contains coal laminae; rootlets in basal half; sharp basal contact
156.7	0.4	<u>COAL</u> , not sampled; Carbon No. 6 Rider coal bed; sharp basal contact
157.1	5.4	INTERBEDDED CLAYSTONE AND CLAY SHALE, medium gray (N5) to medium light gray (N6); rootlets, grass, reeds, and leaves; sharp basal contact
162.5	1.0	SANDSTONE, light gray (N7) to very light gray (N8); silty to very fine grained; jumbled in core barrel
163.5	7.0	CORE LOSS
170.5	3.1	SILTSTONE, light olive gray (5Y6/1) to medium light gray (N6); calcareous in places; sharp basal contact
173.6	6.2	SANDSTONE, light gray (N7) to very light gray (N8); silty to very fine grained; ripplemarked and cross-bedded; calcareous in places
179.8	9.7	CORE LOSS
189.5	7.0	SANDSTONE, light gray (N7) to very light gray (N8); fine to medium grained; calcareous in places
196.5	3.0	CORE LOSS
199.5	3.0	SANDSTONE, very light gray (N8) to light gray (N7); fine to medium grained; calcareous in places
202.5	7.0	CORE LOSS
209.5	4.0	CLAYSTONE, mottled olive gray (5Y4/1) and brownish black (5YR2/1); brecciated appearance; rootlets
213.5	1.0	CORE LOSS
214.5	0.5	SANDSTONE, very light gray (N8); fine grained; unconformable basal contact
215.0	1.5	CLAYSTONE, medium gray (N5); plant debris; sharp basal contact
216.5	8.2	SANDSTONE, very light gray (N8); fine grained to pebbly; two fining upward units, 3-4 feet thick; calcareous in places; coalified bark; unconformable basal contact

CORE HOLE WGS-C3, CONTINUEDSHEET 4 OF 8

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
224.7		INTERBEDDED SILTSTONE AND CLAYSTONE, medium gray (N5) to medium light gray (N6); shaly in places; ripple-marked; leaves, grass, and rootlets; sharp basal contact
	7.8	
232.5		COAL, Sample No. 76-14; Upper Carbon No. 6 coal bed; sharp basal contact
	6.2	
238.7		CLAY SHALE, grayish black (N2) to brownish black (5YR2/1); coal laminae
	1.0	
239.7		COAL, not sampled; Lower Carbon No. 6 coal bed; sharp basal contact
	1.3	
241.0		CLAY SHALE, grayish black (N2) grading down into medium dark gray (N4); coal laminae at top; rootlets, grass, reeds, and leaves; sharp basal contact
	5.2	
246.2		SHALY COAL, not sampled; unnamed coal bed; sharp basal contact
	0.4	
246.6		CLAYSTONE, medium dark gray (N4) to medium gray (N5); shaly in places; silty in places; rootlets; gradational basal contact
	6.5	
253.1		INTERLAMINATED AND INTERBEDDED COAL AND CLAY SHALE, grayish black (N2) to medium dark gray (N4) clay shale; coal interbeds to 0.3 feet thick; plant debris; gradational basal contact
	2.7	
255.8		INTERBEDDED CLAYSTONE AND CLAY SHALE, mottled medium gray (N5) and olive gray (5Y4/1); brecciated appearance in places; rootlets; sharp basal contact
	6.2	
262.0		COAL, not sampled; unnamed coal bed; sharp basal contact
	0.6	
262.6		INTERBEDDED CLAYSTONE AND CLAY SHALE, medium gray (N5) to medium light gray (N6); upper 0.4 feet plastic; brecciated appearance in places; rootlets; gradational basal contact
	3.9	
266.5		INTERLAMINATED COAL AND CLAY SHALE, grayish black (N2) to dark gray (N3) shale; coal laminae less than 25% of unit; plant debris; sharp basal contact
	1.0	
267.5		CLAYSTONE, dark gray (N3) to medium dark gray (N4); sharp basal contact
	0.6	
268.1		COAL, Sample No. 76-15, Upper Carbon No. 7 (upper-bench) coal bed; sharp basal contact
	1.7	
269.8		INTERLAMINATED COAL AND CLAY SHALE, grayish black (N2) shale; coal laminae less than 25% of unit; sharp basal contact
	0.5	

CORE HOLE WGS-C3, CONTINUED

SHEET 5 OF 8

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
270.3	2.1	COAL, Sample No. 76-16, Upper Carbon No. 7 (lower bench) coal bed; sharp basal contact
272.4	2.0	CLAYSTONE, medium gray (N5) to medium light gray (N6); rootlets; sharp basal contact
274.4	1.9	SILT-SAND LAMINITE, medium light gray (N6) silt and light gray (N7) sand; silty to very fine grained sand; calcareous in places; roots and rootlets; gradational basal contact
276.3	4.5	INTERBEDDED CLAYSTONE AND CLAY SHALE, medium gray (N5) to medium light gray (N6); rootlets; basal 0.5 feet jumbled and loose in core barrel
280.8	2.4	CLAY SHALE, medium gray (N5); freshwater gastropod operculae; leaves, reeds, and grass; sharp basal contact
283.2	2.0	COAL, Sample No. 76-17; Lower Carbon No. 7; sharp basal contact
285.2	8.5	CLAYSTONE, brownish gray (5YR4/1); upper 0.2 feet has brecciated appearance; rootlets and plant debris; sharp basal contact
293.7	6.0	INTERBEDDED COAL, CLAYSTONE, AND INTERLAMINATED COAL AND CLAY SHALE, brownish gray (5YR4/1) claystone and medium dark gray (N4) to grayish black (N2) clay shale; coal interbeds to 0.5 feet thick; most units 0.3-0.5 feet thick; claystones contain rootlets; clay shales contain plant debris; sharp basal contact
299.7	24.3	CLAYSTONE, medium gray (N5) to brownish gray (5YR4/1); rootlets and roots; gradational basal contact
324.0	7.9	INTERBEDDED SILTSTONE AND CLAYSTONE, medium gray (N5); rootlets; gradational basal contact
331.9	27.6	CLAYSTONE, medium dark gray (N4) to light olive gray (5Y6/1); brecciated appearance in places; rootlets; thin calcareous sandstone interbed just below middle (0.1 feet thick); gradational basal contact
359.5	2.0	CLAY SHALE, medium dark gray (N4), becomes dark gray (N3) at base with coal laminae; leaves, reeds, grass, and plant debris; sharp basal contact
361.5	4.6	INTERBEDDED CLAYSTONE AND SILTSTONE, medium light gray (N6) to greenish gray (5GY6/1); gradational interbeds; rootlets at top; gradational basal contact

CORE HOLE WGS-C3, CONTINUEDSHEET 6 OF 8

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
366.1		SILTSTONE, light gray (N7) to medium dark gray (N4); interlaminated with silty to very fine grained sand near base; rootlets, grass, leaves, and plant debris; sharp basal contact
	3.6	
369.7		SANDSTONE, light gray (N7) to very light gray (N8); silty to fine grained; calcareous; bark and plant debris; gradational basal contact
	2.2	
371.9		CLAYSTONE, medium light gray (N6); silty; plant debris; gradational basal contact
	1.7	
372.2		INTERBEDDED SILT SHALE AND SANDSTONE, medium light gray (N6) shale and very light gray (N8) sand; 0.3-0.6 feet thick units with sharp contacts; sandstones are calcareous; roots, leaves, grass, and reeds; sharp basal contact
	3.2	
375.4		INTERBEDDED CLAYSTONE, CLAY SHALE, AND INTERLAMINATED COAL AND CLAY SHALE, brownish gray (5YR4/1) claystone and medium light gray (N6) to dark gray (N3) clay shale; 0.2-1.3 feet thick interbeds; freshwater ostracodes; rootlets, grass, reeds, and leaves; basal 0.4 feet jumbled and loose in core barrel
	4.6	
380.0		SILT SHALE, medium dark gray (N4) and medium light gray (N6) color laminations (varve-like); freshwater gastropods, gastropod operculae, ostracodes, and fish bones; leaves, grass, and plant debris; gradational basal contact
	7.3	
387.3		CLAY SHALE, medium dark gray (N4) and medium gray (N5) color laminations (varve-like); fish bones at top of unit; leaves at top of unit; sharp basal contact
	3.3	
390.6		SANDSTONE, light gray (N7) to very light gray (N8); very fine grained to granular sand with medium gray (N5) shale-pebble zones common; nine fining upward units, 3-15 feet thick; cross-bedded; plant debris and coalified bark; sharp basal contact
	58.0	
448.6		COAL, Sample No. 76-18; Bed No. 111 coal; sharp basal contact
	3.4	
452.0		SILTSTONE, medium light gray (N6) with light gray (N7), very fine to fine grained sandy interbeds at base; calcareous in places; roots and rootlets; sharp basal contact
	5.5	

CORE HOLE WGS-C3, CONTINUED

SHEET 7 OF 8

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
457.5	11.9	SANDSTONE, light gray (N7) to very light gray (N8); very fine grained to granular with medium gray (N5) shale-pebble zones; three fining upward units, 2-5 feet thick; cross-bedded; calcareous in places; coalified bark and plant debris; unconformable basal contact
469.4	5.3	INTERBEDDED SILTSTONE AND CLAYSTONE, light gray (N7) silt and medium gray (N5) clay; shaly at top and bottom; rootlets, grass, reeds, and plant debris; sharp basal contact
474.7	4.9	CLAYSTONE, dark greenish gray (5GY4/1) to medium gray (N5); rootlets; sharp basal contact
479.6	8.7	INTERBEDDED SILT SHALE, CLAY SHALE, AND SANDSTONE, medium light gray (N6) silt, medium gray (N5) clay, and light gray (N7) sand; silty to very fine grained sandstone units to one foot thick, calcareous; ripplemarked; clay-silt-sand laminite in places; leaves, reeds, grass, and plant debris; sharp basal contact
488.3	11.3	SANDSTONE, light gray (N7) to very light gray (N8); silty to fine grained; ripplemarked; calcareous in places; leaves and plant debris
499.6	2.0	CORE LOSS
501.6	65.2	SANDSTONE, light gray (N7) to very light gray (N8); very fine grained to pebbly; six fining upward units, 3-30 feet thick; medium gray (N5) shale-pebble conglomerates 1.7-5.4 feet thick; cross-bedded; calcareous in places; plant debris, leaves, and coalified bark; unconformable basal contact
566.8	3.8	COAL, Sample No. 76-19; Upper Bed No. 109 coal; 1.25 feet thick, grayish black (N2), clay shale parting 1.7 feet below top of coal; sharp basal contact
570.6	3.8	CLAYSTONE, medium dark gray (N4) becoming brownish gray (5YR4/1) downward; shaly at base; leaves, reeds, roots, and rootlets; gradational basal contact
574.4	3.1	SILTSTONE, medium gray (N5); leaves, grass, reeds, roots; gradational basal contact
577.5	2.1	CLAYSTONE, medium gray (N5) becoming dark gray (N3) downward; roots, rootlets, and leaves; sharp basal contact

CORE HOLE WGS-C3, CONTINUEDSHEET 8 OF 8

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
579.6	1.0	COAL, not sampled; Lower Bed No. 109; sharp basal contact
580.6	0.7	CLAY SHALE, medium dark gray (N4) becoming medium light gray (N6) downward; silty downward; leaves and plant debris; sharp basal contact
581.3	5.1	SAND-SILT LAMINITE, light olive gray (5Y6/1) sand and dark gray (N3) to medium gray (N5) silt; ripple-marked; leaves, reeds, and grass; gradational basal contact
586.4	6.8	INTERBEDDED SILT AND CLAY SHALE, medium dark gray (N4) to medium gray (N5); leaves, reeds, and grass; gradational basal contact
593.2	27.5	SANDSTONE, light gray (N7) to very light gray (N8); silty to very coarse sand with medium gray (N5) shale-pebble zones; four fining upward units, 3-7 feet thick; cross-bedded; calcareous in places; plant debris
620.7		
		TOTAL CORE LOSS 83.1 feet
		OVERALL RECOVERY 86.6%

CORE HOLE WGS-C3A

Location: 190 feet north and 1,275 feet west from the SE corner of Section 35, T.22N., R.80W.



STATE: Wyoming
 COUNTY: Carbon
 QUADRANGLE: Halfway Hill
 COAL-BEARING AREA: Hanna
 COAL FIELD: Hanna

DATE OF COMPLETION: 11/21/76
 TOTAL DEPTH: 209.2 feet
 SURFACE ELEVATION: 6950
 LOGGED BY: Gary B. Glass
 STRIKE:
 DIP: Horizontal

GEOLOGIC FORMATION: Hanna
 AGE: Paleocene

SHEET 1 OF 2

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
0	76.0	Not cored; no samples taken; see WGS-C3 for details
76.0		SANDSTONE, light gray (N7) to very light gray (N8); silty to pebbly sand with medium gray (N5) shale-pebble zones; three fining upward units, 2.5-10 feet thick; cross-bedded in places; calcareous in places; coalified bark
	15.9	
91.9	3.0	CORE LOSS
94.9		SANDSTONE, light gray (N7) to very light gray (N8); very fine grained to pebbly sand with medium gray (N5), shale-pebble zones; three fining upward units, 4-13 feet thick; cross-bedded; coalified bark and logs
	23.4	
118.3	1.7	CORE LOSS
120.0		SANDSTONE, medium light gray (N6) to light gray (N7); fine grained to granular sand; two fining upward units, 3-6.4 feet thick; cross-bedded; calcareous in places; coalified bark
	9.4	
129.4	0.6	CORE LOSS
130.0		SANDSTONE, medium light gray (N6) to light gray (N7); medium to very coarse grained; fining upward unit; cross-bedded; unconformable basal contact
	4.3	
134.3		<u>SHALY COAL</u> , not sampled; Carbon No. 6 Rider coal bed; portions broken and jumbled in core barrel
	1.0	
135.3		CLAYSTONE, dark gray (N3) to brownish gray (5YR4/1); broken and jumbled in core barrel
	0.3	
135.6	1.4	CORE LOSS
137.0		CLAY SHALE, medium dark gray (N4); leaves, reeds, and grass
	2.9	

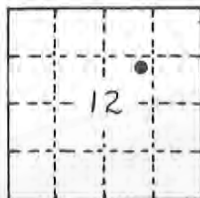
CORE HOLE WGS-C3A, CONTINUED

SHEET 2 OF 2

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
139.9	4.0	CORE LOSS
143.9	5.2	CLAYSTONE, medium dark gray (N4) becomes dark gray (N3) and shaly at top and bottom of unit; leaves, reeds, grass, and plant debris
149.1	1.9	CORE LOSS
151.0	1.9	CLAY SHALE, grayish black (N2) to dark gray (N3); coal laminae common; plant debris; sharp basal contact
152.9	0.4	COAL, not sampled; Carbon No. 6 Rider coal bed; sharp basal contact
153.3	6.3	CLAY SHALE, medium dark gray (N4); leaves, grass, and reeds; gradational basal contact
159.6	10.4	CLAYSTONE, medium gray (N5); roots, rootlets, and leaves; sharp basal contact
170.0	9.2	SILTSTONE, medium gray (N5); few fine grained sandstone interbeds to 0.5 feet thick; base marked by broken, jumbled core
179.2	4.5	SANDSTONE, very light gray (N8); fine grained; cross-bedded
183.7	1.0	CORE LOSS
184.7	10.7	SANDSTONE, light gray (N7) to very light gray (N8); fine to medium grained; cross-bedded
195.4	3.6	CORE LOSS
199.0	10.2	SANDSTONE, light gray (N7) to very light gray (N8); medium to coarse grained; fining upward unit; cross-bedded; calcareous in places
209.2		
		TOTAL CORE LOSS 17.2 feet
		OVERALL RECOVERY 91.8%

CORE HOLE WGS-C4

Location: 1,600 feet south and 1,540 feet west from the NE corner of
Section 12, T.21N., R.80W.



STATE: Wyoming
COUNTY: Carbon
QUADRANGLE: Halfway Hill
COAL-BEARING AREA: Hanna
COAL FIELD: Hanna

DATE OF COMPLETION: 7/7/77
TOTAL DEPTH: 702.9 feet
SURFACE ELEVATION: 7040
LOGGED BY: Gary B. Glass
STRIKE: 90°
DIP: 1-2° N

GEOLOGIC FORMATION: Hanna
AGE: Paleocene

SHEET 1 OF 8

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
0	12.0	Air-drilled; no core; probably sandstone
12.0		SANDSTONE, yellowish gray (5Y7/2); silty to coarse grained sand with medium dark gray (N4) shale-pebble zones; six fining upward units, 3-17 feet thick; ripplemarked and cross-bedded in places; calcareous in places; plant debris; unconformable basal contact
	37.6	
49.6		INTERBEDDED CLAY SHALE AND CLAYSTONE, medium gray (N5); silty downward with very fine grained sandy zones to 0.5 feet thick; leaves near base; sharp basal contact
	12.5	
62.1		CLAY SHALE, medium dark gray (N4) becoming dark gray (N3) downward; coal laminae; rootlets; sharp basal contact
	1.9	
64.0		COAL, Sample No. 77-1; Carbon No. 6 Rider coal bed; sharp basal contact
	1.95	
65.95		CLAY SHALE, grayish black (N2) to medium dark gray (N4); coal laminae abundant; rootlets and plant debris; sharp basal contact
	2.35	
68.3		SHALY COAL, not sampled; Carbon No. 6 Rider coal bed; sharp basal contact
	0.9	
69.2		INTERBEDDED CLAYSTONE, CLAY SHALE, AND INTERLAMINATED COAL AND CLAY SHALE, brownish gray (5YR4/1) claystone and grayish black (N2) to dark gray (N3) clay shale; 0.3-1.1 feet thick interbeds; rootlets; sharp basal contact
	4.5	
73.7		SHALY COAL, not sampled; Carbon No. 6 Rider coal bed; sharp basal contact
	1.1	

CORE HOLE WGS-C4, CONTINUEDSHEET 2 OF 8

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
74.8	11.7	INTERBEDDED CLAY SHALE AND CLAYSTONE, medium dark gray (N4) to medium gray (N5); rootlets, grass, leaves; sharp basal contact
86.5	1.4	COAL, not sampled; Uppr Carbon No. 6 coal bed; sharp basal contact
87.9	3.1	SILT-CLAY-SAND LAMINITE, medium light gray (N6) silt and sand and medium dark gray (N4) clay; silty to very fine grained sand; roots, rootlets, and leaves; gradational basal contact
91.0	6.4	SANDSTONE, light gray (N7) to very light gray (N8); silty to fine grained; ripplemarked; calcareous in places; plant debris; gradational basal contact
97.4	0.6	SILTSTONE, medium light gray (N6) becomes medium gray (N5) and clayey downward; leaves, grass, and rootlets; sharp basal contact
98.0	6.7	SANDSTONE, light gray (N7) to very light gray (N8); silty to fine grained; cross-bedded; calcareous in places; unconformable basal contact
104.7	1.7	SILT-CLAY LAMINITE, medium gray (N5) silt and medium dark gray (N4) to dark gray (N3) clay; leaves and plant debris; sharp basal contact
106.4	0.9	SHALY COAL, not sampled; Lower Carbon No. 6 coal bed; sharp basal contact
107.3	6.5	INTERBEDDED CLAY SHALE AND SHALY COAL, grayish black (N2) to dark gray (N3) shale; 0.1-1.3 feet thick shale interbeds, coals 0.6-0.8 feet thick; rootlets; gradational basal contact
113.8	1.8	SAND-SILT LAMINITE, medium light gray (N6) sand and medium gray (N5) silt; silty to very fine grained sand; ripplemarked; plant debris and rootlets; sharp basal contact
115.6	1.5	CLAYSTONE, olive gray (5Y4/1); rootlets; sharp basal contact
117.1	3.1	CLAY SHALE, grayish black (N2) at top grading down into olive gray (5Y4/1); freshwater gastropod operculae; leaves, grass, and reeds; gradational basal contact
120.2	12.1	SANDSTONE, light gray (N7) to very light gray (N8); very fine to fine grained; ripplemarked; calcareous near base; burrowed; leaves, bark, and twigs; sharp basal contact

CORE HOLE WGS-C4, CONTINUEDSHEET 3 OF 8

DEPTH (Feet)	THICK- NESS (Feet)	
132.3		INTERBEDDED CLAYSTONE AND INTERLAMINATED COAL AND CLAY SHALE, medium gray (N5) claystone and grayish black (N2) clay shale; 0.1-1.6 feet thick interbeds; plant debris and rootlets; sharp basal contact
	3.4	
135.7		CLAYSTONE, medium gray (N5) becoming dark gray (N3) and shaly at base; plant debris; coal laminae at base; gradational basal contact
	2.5	
138.2		CLAYSTONE, olive gray (5Y4/1); roots and rootlets; sharp basal contact
	4.1	
142.3		<u>SHALY COAL</u> , not sampled; Carbon No. 7 Rider coal bed; sharp basal contact
	1.5	
143.8		INTERBEDDED CLAYSTONE, CLAY SHALE, AND INTERLAMINATED COAL AND CLAY SHALE, medium dark gray (N4) claystone, olive gray (5Y4/1) to grayish black (N2) clay shale; plant debris and rootlets; sharp basal contact
	3.5	
147.3		<u>COAL</u> , not sampled; Upper Carbon No. 7 (upper bench) coal bed; sharp basal contact
	1.5	
148.8		CLAYSTONE, dark gray (N3) to olive black (5Y2/1); coal interbed at middle, 0.3 feet thick; sharp basal contact
	1.2	
150.0		<u>SHALY COAL</u> , not sampled; Upper Carbon No. 7 (lower bench) coal bed; sharp basal contact
	1.4	
151.4		INTERBEDDED CLAY SHALE AND INTERLAMINATED COAL AND CLAY SHALE, medium dark gray (N4) to grayish black (N2) clay shale; leaves, reeds, grass, rootlets, and plant debris; sharp basal contact
	3.5	
154.9		<u>COAL</u> , not sampled; Lower Carbon No. 7 coal bed; sharp basal contact
	2.1	
157.0		INTERBEDDED CLAY SHALE, COAL, AND INTERLAMINATED COAL AND CLAY SHALE, grayish black (N2) to dark gray (N3) clay shale; coal interbeds to 0.8 feet thick; rootlets, leaves, reeds, and plant debris; gradational basal contact
	8.8	
165.8		CLAYSTONE, medium gray (N5); silty at base; rootlets; mottled brownish gray (5YR4/1) and brownish black (5YR2/1) at top
	3.5	
169.3		CORE LOSS
	3.0	

CORE HOLE WGS-C4, CONTINUED

SHEET 4 OF 8

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
172.3	13.2	INTERBEDDED SILTSTONE AND CLAYSTONE, medium light gray (N6) to light olive gray (5Y6/1); sharp basal contact
185.5	12.1	INTERBEDDED SANDSTONE AND CLAY SHALE, medium light gray (N6) to light gray (N7) sand and dark gray (N3) to medium gray (N5) clay shale; 0.5-2.6 feet thick interbeds; silty to fine grained sand; ripplemarked; sandstones burrowed; plant debris; gradational basal contact
197.6	7.9	CLAY SHALE, medium dark gray (N4) to dark gray (N3) with medium light gray (N6) sand lenses at top; varve-like, color laminae; freshwater pelecypods and gastropod operculae; leaves; gradational basal contact
205.5	2.0	CLAYSTONE, dark greenish gray (5G4/1) to medium gray (N5); rootlets; gradational basal contact
207.5	1.0	CLAYSTONE, mottled light olive gray (5Y6/1) and olive gray (5Y4/1); brecciated appearance; rootlets; unconformable basal contact
208.5	105.9	SANDSTONE, very light gray (N8) to light gray (N7); fine grained to pebbly sand with medium gray (N5) shale-pebble zones; nine fining upward units, 3-40 feet thick; cross-bedded in places; calcareous in places; coalified bark; sharp basal contact
314.4	3.2	<u>SHALY COAL</u> , Sample No. 77-2; Bed No. 111 coal; sharp basal contact
317.6	4.4	INTERBEDDED SILTSTONE AND SANDSTONE, olive gray (5Y4/1) siltstone and light gray (N7) sandstone; silty to very fine grained sand; sandstone interbeds increase downward; burrowed in basal 2 feet; roots and rootlets at top; sharp basal contact
322.0	6.3	CLAY SHALE, medium gray (N5) to medium dark gray (N4) color laminae; freshwater ostracodes, gastropod operculae, and fish vertebrae; leaves, reeds, and roots; gradational basal contact
328.3	0.4	INTERLAMINATED COAL AND CLAY SHALE, grayish black (N2) clay shale; coal laminae make up less than 10% of unit; reeds, grass, and plant debris; gradational basal contact

CORE HOLE WGS-C4, CONTINUED

SHEET 5 OF 8

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
328.7	2.5	INTERBEDDED CLAY SHALE AND SANDSTONE, medium dark gray (N4) to medium light gray (N6) shale and very light gray (N8) sandstone; fine to medium grained sand; 0.2-1.1 feet thick interbeds; rootlets; gradational basal contact
331.2	8.8	INTERBEDDED SANDSTONE AND SILTSTONE, medium gray (N5) silt and light gray (N7) sand; silty to fine grained sand; gradational to sharp interbed contacts; 0.5-12 inch thick interbeds; burrowed; leaves and plant debris; sharp basal contact
340.0	68.4	SANDSTONE, light gray (N7) to very light gray (N8), silty to very coarse grained sand with medium gray (N5) shale and siltstone pebbles and cobbles in units up to 8.4 feet thick; six fining upward units, 2.5-18 feet thick; cross-bedded in places; calcareous in places; leaves, coalified bark, and plant debris; sharp basal contact
408.4	0.8	SHALY COAL, not sampled; unnamed coal above the Bed No. 109 coal; sharp basal contact
409.2	1.5	SILTSTONE, light olive gray (5Y6/1); sandy downward; roots and rootlets; gradational basal contact
410.7	1.6	SANDSTONE, medium light gray (N6) to light gray (N7); silty to very fine grained; roots and rootlets; sharp basal contact
412.3	0.2	CLAYSTONE, olive black (5Y2/1) to grayish black (N2); rootlets
412.5	1.0	CORE LOSS
413.5	4.5	INTERBEDDED CLAYSTONE AND CLAY SHALE, olive gray (5Y4/1) to brownish gray (5YR4/1) claystone and olive black (5Y2/1) clay shale; coal laminae in places; roots and rootlets; sharp basal contact
418.0	1.8	COAL, not sampled; Upper Bed No. 109 coal bed; up to 0.7 feet lost in coring; sharp basal contact
419.8	2.2	INTERBEDDED CLAY SHALE AND CLAYSTONE, grayish black (N2) shale and olive black (5Y2/1) to brownish gray (5YR4/1) claystone; grades into a 0.2 feet thick coal at base; rootlets; sharp basal contact
422.0	3.0	CLAYSTONE, light olive gray (5Y6/1) to brownish gray (5YR4/1), mottled near base with brecciated appearance; roots and rootlets

CORE HOLE WGS-C4, CONTINUEDSHEET 6 OF 8

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
425.0	0.5	CORE LOSS
425.5	3.0	CLAYSTONE, greenish gray (5GY6/1) to olive gray (5Y4/1); gradational basal contact
428.5	0.4	CLAY SHALE, grayish black (N2); coal laminae make up less than 10% of unit; sharp basal contact
428.9	0.6	COAL, not sampled; Lower Bed No. 109 coal bed; sharp basal contact
429.5	3.2	CLAY SHALE, olive gray (5Y4/1); vague color laminae; rootlets, twigs, leaves; coalified bark; sharp basal contact
432.7	1.5	CLAYSTONE, mottled light olive gray (5Y6/1) and olive black (5Y2/1); brecciated appearance; rootlets; gradational basal contact
434.2	6.8	SILTSTONE, light olive gray (5Y6/1); roots; sharp basal contact
441.0	9.9	INTERBEDDED CLAY SHALE AND CLAYSTONE, olive gray (5Y6/1) to olive black (5Y2/1) shale and light olive gray (5Y6/1) to greenish gray (5GY6/1) claystone; 0.5-3.3 feet thick interbeds; rootlets, leaves, and plant debris
450.9	1.3	CORE LOSS
452.2	0.3	CLAY SHALE, olive gray (5Y4/1) silty; roots and plant debris; sharp basal contact
452.5	1.6	SANDSTONE, light brownish gray (5YR6/1) to medium light gray (N6); silty to very fine grained; roots; gradational basal contact
454.1	2.7	CLAYSTONE, light olive gray (5Y6/1); roots and rootlets; gradational lower contact
456.8	4.0	INTERBEDDED SILTSTONE AND SANDSTONE, medium gray (N5) silt and light gray (N7) sand; silty to very fine grained sand; ripplemarked; burrows; roots, reeds, and grass; gradational basal contact
460.8	2.3	CLAYSTONE, medium gray (N5); roots and rootlets; gradational basal contact
463.1	8.3	INTERBEDDED SANDSTONE AND SILTSTONE, light gray (N7) sand and medium gray (N5) silt; silty to fine grained sand; sharp contacts between interbeds; ripplemarked at top, cross-bedded near base; burrows; leaves, reeds, roots, and rootlets; basal contact not seen

CORE HOLE WGS-C4, CONTINUEDSHEET 7 OF 8

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
471.4	5.8	CLAYSTONE, medium dark gray (N4) to greenish gray (5GY6/1); sharp basal contact
477.2	2.5	SILTSTONE, medium light gray (N6) to light bluish gray (5B5/1); sandy at top; gradational basal contact
479.7	1.9	INTRAFORMATIONAL BRECCIA, medium bluish gray (5B5/1) claystone fragments in a light bluish gray (5B7/1) matrix of silt or very fine grained sand; matrix material fines upward; basal contact not seen
481.6	2.4	CLAY SHALE, medium dark gray (N4); reeds; gradational lower contact
484.0	39.9	SANDSTONE, light gray (N7) to very light gray (N8); silty to granular sand; top 4.5 feet ripplemarked; six fining upward units, 3-7 feet thick; cross-bedded; calcareous in places; coalified bark; sharp basal contact
523.9	8.2	INTERBEDDED CLAY SHALE AND SILT SHALE, dark gray (N3) to medium dark gray (N4) clay shale and medium gray (N5) silt shale; freshwater gastropod operculae at top of unit; leaves and grass at top of unit; sharp basal contact
532.1	111.2	SANDSTONE, light gray (N7) to very light gray (N8); very fine grained to granular sand with medium gray (N5) shale and siltstone pebbles; 18 fining upward units, 2-24 feet thick; cross-bedded; calcareous in places; coalified bark; unconformable basal contact
643.3	11.9	PEBBLY SANDSTONE, light gray (N7); medium to very coarse grained sand with numerous, randomly-oriented, medium gray (N5), shale and siltstone pebbles and cobbles; matrix material fines upward; gradational basal contact
655.2	13.4	SANDSTONE, light gray (N7); medium to very coarse grained with occasional medium gray (N5) shale-pebbles; fining upward unit; calcareous in places; gradational basal contact
668.6	9.8	SHALE-PEBBLE CONGLOMERATE, medium gray (N5) shale and siltstone pebbles in a light gray (N7) coarse to very coarse grained matrix of sand; fining upward unit; pebbles randomly oriented; calcareous in places; sharp basal contact

CORE HOLE WGS-C4, CONTINUEDSHEET 8 OF 8

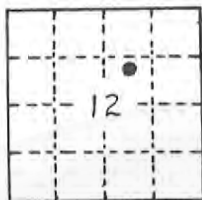
DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
678.4		SANDSTONE, light gray (N7) to very light gray (N8);
	24.5	fine grained to granular sand with medium gray (N5)
		shale-pebble zones; five fining upward units; 2-10
		feet thick; cross-bedded; calcareous in places
702.9		

TOTAL CORE LOSS 6.5 feet

OVERALL RECOVERY: 99.1%

DRILL HOLE WGS-C4A

Location: 1,600 feet south and 1,550 feet west from the NE corner of
Section 12, T.21N., R.80W.



STATE: Wyoming
COUNTY: Carbon
QUADRANGLE: Halfway Hill
COAL-BEARING AREA: Hanna
COAL FIELD: Hanna

DATE OF COMPLETION: 7/8/77
TOTAL DEPTH: 310 feet
SURFACE ELEVATION: 7040
LOGGED BY: Gary B. Glass
STRIKE: 90°
DIP: 1-2° N

GEOLOGIC FORMATION: Hanna
AGE: Paleocene

SHEET 1 OF 1

DEPTH (Feet)	THICK- NESS (Feet)	DESCRIPTION
0	310	Air-drilled; no cutting samples or core; see CORE HOLE WGS-C4 for description of section
310		

APPENDIX B

GEOPHYSICAL LOGS FOR CORE HOLES

WGS-C1, WGS-C2, AND WGS-C3

Geophysical Logs for Core Holes

WGS-C1, WGS-C2, and WGS-C3

As part of the continuing cooperation between mining companies and the Geological Survey of Wyoming, these geophysical logs were run for the Survey by two mining companies at no cost to the Geological Survey of Wyoming or the U.S. Geological Survey. This cooperation did not include exchange of any additional information such as lithologic logs, coal depths, or coal thicknesses. It did allow the company that ran each log to retain a copy of their log after a reproducible copy was provided to the Geological Survey of Wyoming. These logs have been photographically reduced for reproduction on Plate 4.

Two geophysical logs were made of portions of Core Hole WGS-C1. Because the probe hung up on a rock ledge, the first log consisted of gamma and density runs that only penetrated the top 361 feet of the hole (Plate 4). This log was made before any casing was set. A later log, providing gamma, density, and resistivity readings, was run after 310 feet of PVC casing had been emplaced. Only 309 feet was logged to avoid dropping the probe below the casing. Because the density and resistivity readings were made through casing, they are essentially worthless (Plate 4).

Because the drill pipe in Core Hole WGS-C2 couldn't be removed, only a gamma log was run on that hole. Thick mud prevented the probe from penetrating more than 370 feet (Plate 4).

A complete suite of gamma, density, and resistivity logs were made on Core Hole WGS-C3. Unfortunately, mud prevented penetration below 493 feet (Plate 4). The bias reading at 399 feet reflects the top of 180 feet of drill pipe lost in the core hole.

APPENDIX C

DETAILED MEGASCOPIC DESCRIPTIONS
OF COALS ANALYZED FOR THIS REPORT

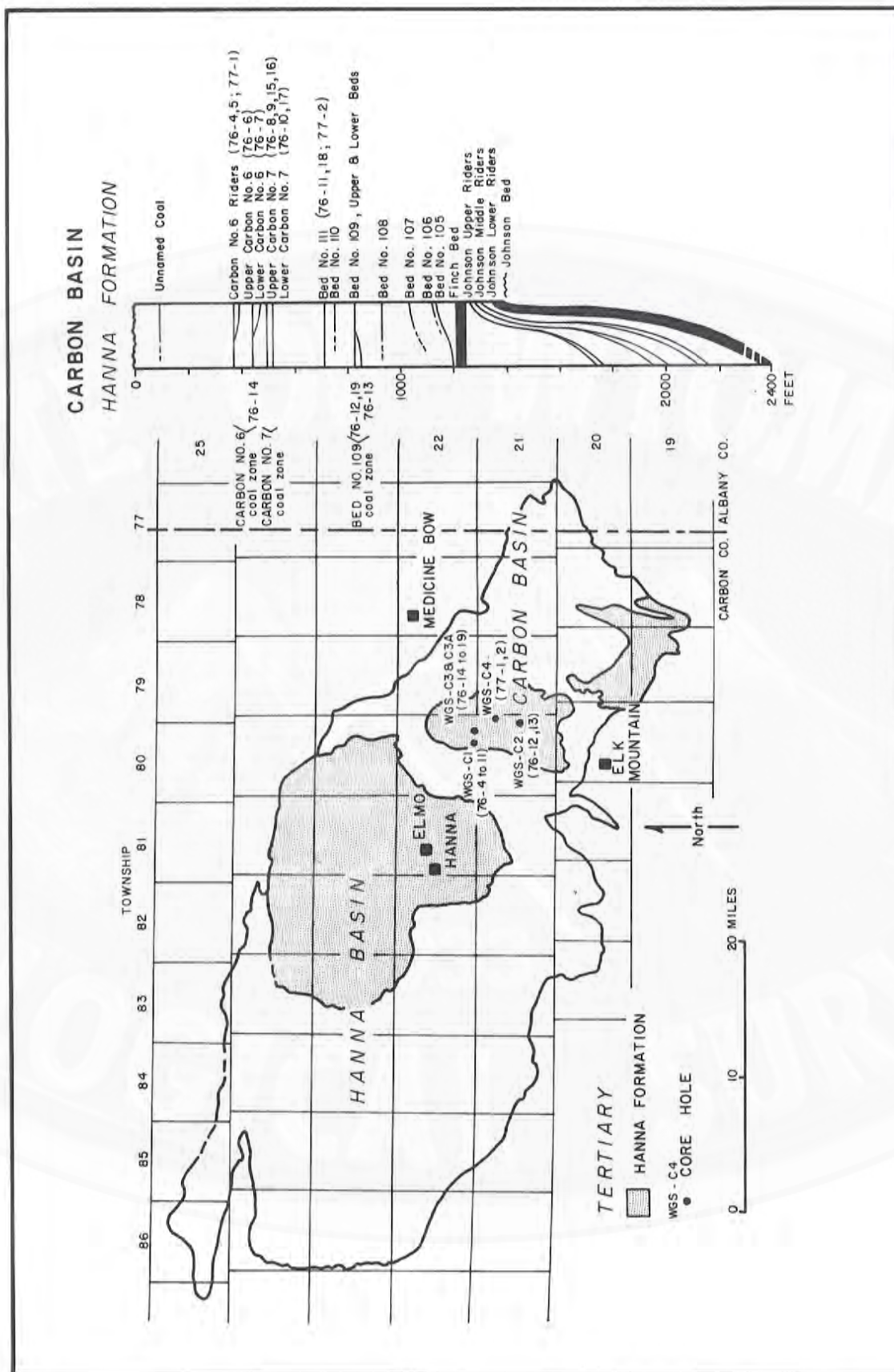


Figure 6. Generalized section and index map for 18 samples (Nos. 76-4 to 76-19, 77-1, and 77-2) collected in the Carbon Basin of southcentral Wyoming

SAMPLE NO. 76-4; Carbon No. 6 Coal Bed

CORE HOLE: WGS-C1

STATE: Wyoming

GEOLOGIC FORMATION: Hanna

COUNTY: Carbon

AGE: Paleocene

SECTION: 34

COAL FIELD: Hanna

TOWNSHIP: 22N.

COAL-BEARING AREA: Hanna

RANGE: 80W.

QUADRANGLE: Carbon



COAL DESCRIPTION: See Figure 7

THICKNESS OF COAL (FEET): 1.2

THICKNESS SAMPLED (FEET): 1.2

CONDITION OF SAMPLE: Unbroken

TYPE OF SAMPLE: Core

DATE OF SAMPLING: September 24, 1976

SAMPLE COLLECTOR: Wyoming Geological Survey

LABORATORY NUMBERS:

Wyoming Geological Survey 76-4

U.S. Bureau of Mines K72359

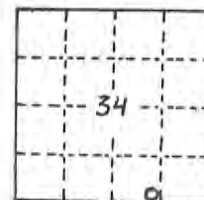
U.S. Geological Survey D188040

MISCELLANEOUS COMMENTS:

Core hole interval 159.0-160.2 feet; elevation on top of coal
is 6881 feet

SAMPLE NO. 76-5: Carbon No. 6 Rider Coal Bed

CORE HOLE: WGS-C1	STATE: Wyoming
GEOLOGIC FORMATION: Hanna	COUNTY: Carbon
AGE: Paleocene	SECTION: 34
COAL FIELD: Hanna	TOWNSHIP: 22N.
COAL-BEARING AREA: Hanna	RANGE: 80W.
	QUADRANGLE: Carbon



COAL DESCRIPTION: See Figure 7
THICKNESS OF COAL (FEET): 1.8
THICKNESS SAMPLED (FEET): 1.8
CONDITION OF SAMPLE: Jumbled in core barrel
TYPE OF SAMPLE: Core

DATE OF SAMPLING: September 24, 1976
SAMPLE COLLECTOR: Wyoming Geological Survey
LABORATORY NUMBERS:

Wyoming Geological Survey	76-5
U.S. Bureau of Mines	K72360
U.S. Geological Survey	D188041

MISCELLANEOUS COMMENTS:

Core hole interval 164.3-166.1 feet; elevation on top of coal
is 6876 feet

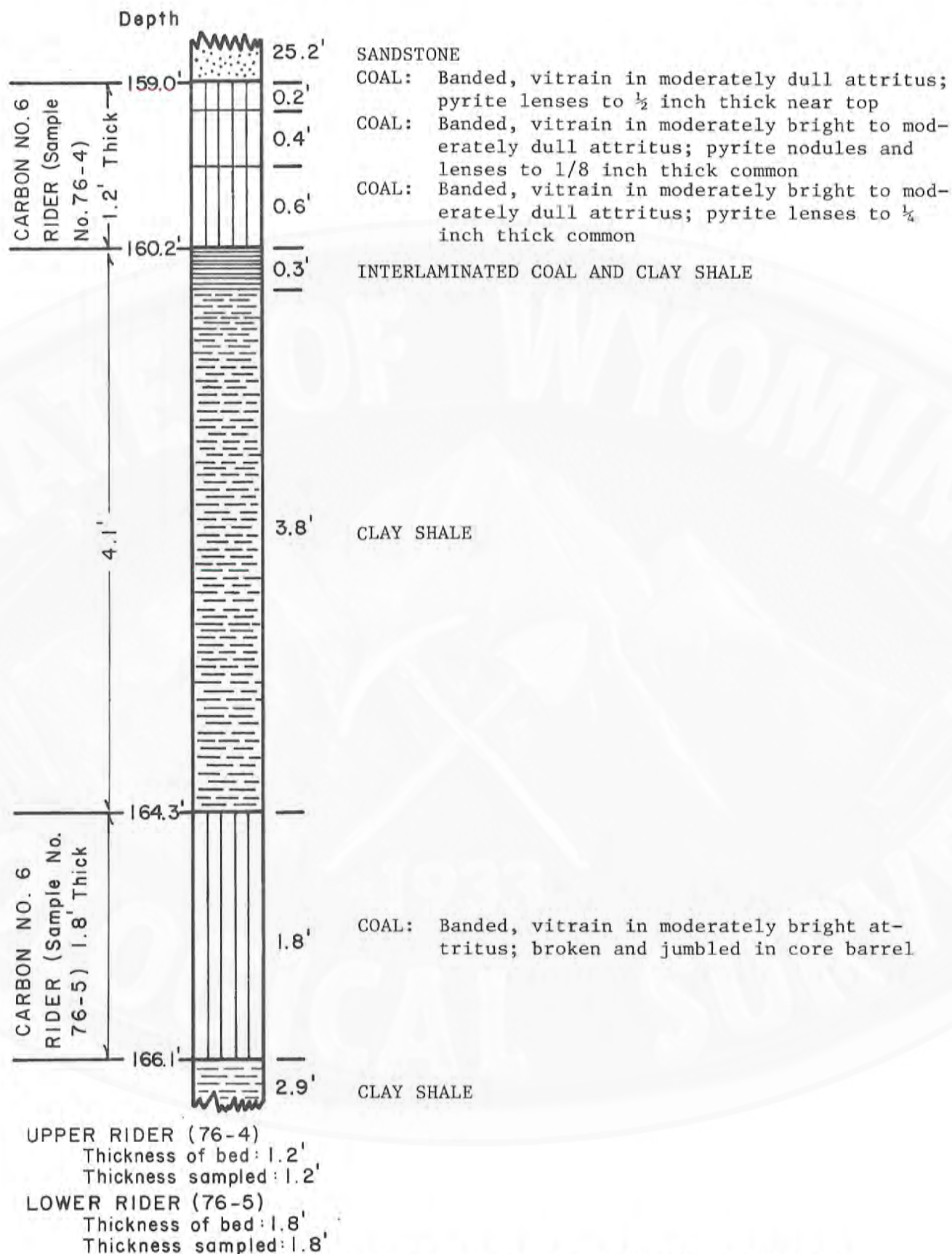


Figure 7. Megascopic descriptions of the Carbon No. 6 Upper and Lower Riders from Core Hole WGS-C1 (Sample Nos. 76-4 and 76-5)

SAMPLE NO. 76-6: Upper Carbon No. 6 Coal Bed

CORE HOLE: WGS-C1	STATE: Wyoming
GEOLOGIC FORMATION: Hanna	COUNTY: Carbon
AGE: Paleocene	SECTION: 34
COAL FIELD: Hanna	TOWNSHIP: 22N.
COAL-BEARING AREA: Hanna	RANGE: 80W.
	QUADRANGLE: Carbon



COAL DESCRIPTION: See Figure 8
 THICKNESS OF COAL (FEET): 2.3
 THICKNESS SAMPLED (FEET): 2.3
 CONDITION OF SAMPLE: Partially broken
 TYPE OF SAMPLE: Core

DATE OF SAMPLING: September 25, 1976
 SAMPLE COLLECTOR: Wyoming Geological Survey
 LABORATORY NUMBERS:

Wyoming Geological Survey	76-6
U.S. Bureau of Mines	K72361
U.S. Geological Survey	D188042

MISCELLANEOUS COMMENTS:

Core hole interval 214.7-217.0 feet; elevation on top of coal
 is 6825 feet

SAMPLE NO. 76-7: Lower Carbon No. 6 Coal Bed

CORE HOLE: WGS-C1

STATE: Wyoming

GEOLOGIC FORMATION: Hanna

COUNTY: Carbon

AGE: Paleocene

SECTION: 34

COAL FIELD: Hanna

TOWNSHIP: 22N.

COAL-BEARING AREA: Hanna

RANGE: 80W.

QUADRANGLE: Carbon



COAL DESCRIPTION: See Figure 8

THICKNESS OF COAL (FEET): 1.6

THICKNESS SAMPLED (FEET): 1.6

CONDITION OF SAMPLE: Unbroken

TYPE OF SAMPLE: Core

DATE OF SAMPLING: September 25, 1976

SAMPLE COLLECTOR: Wyoming Geological Survey

LABORATORY NUMBERS:

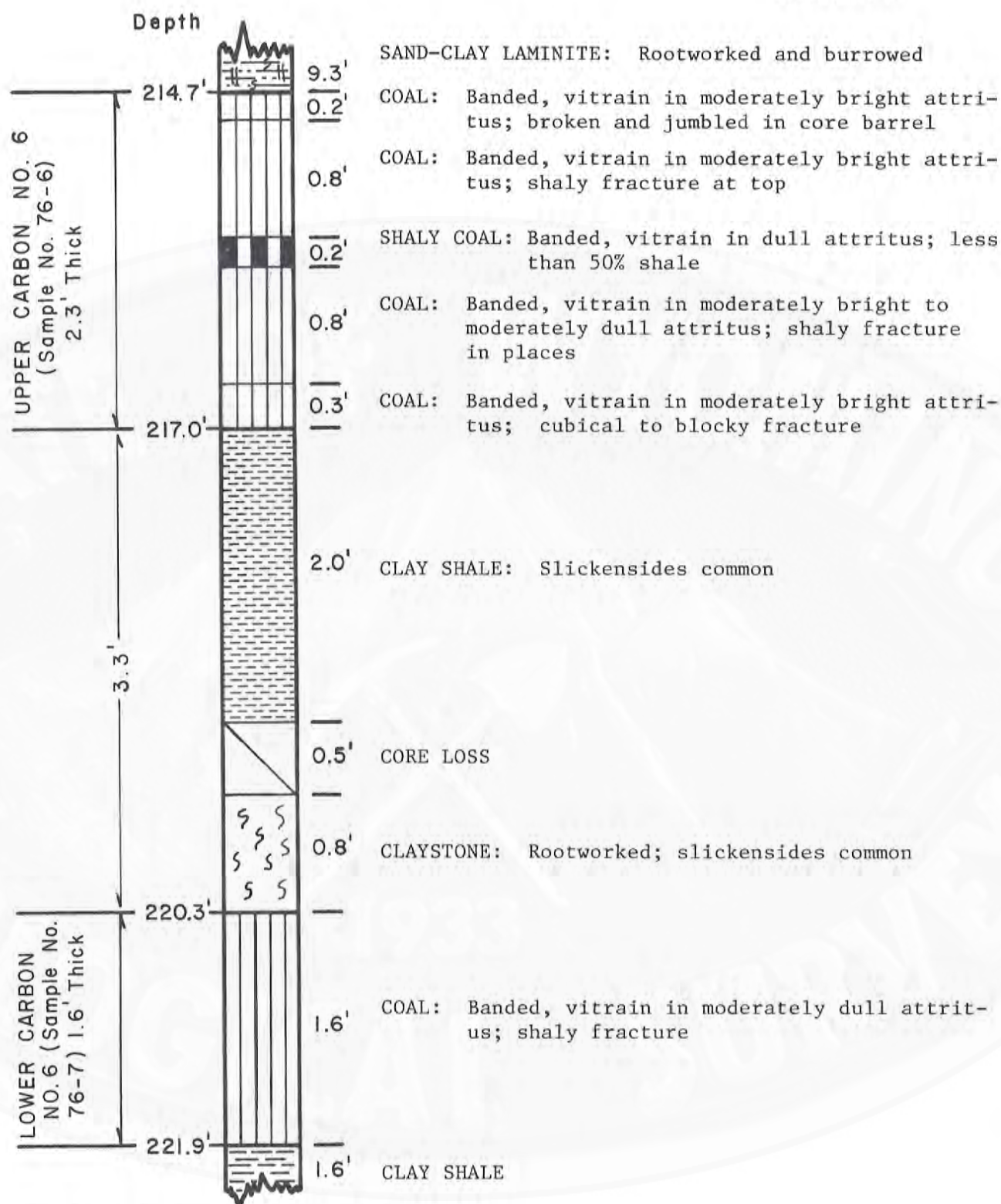
Wyoming Geological Survey 76-7

U.S. Bureau of Mines K72362

U.S. Geological Survey D188043

MISCELLANEOUS COMMENTS:

Core hole interval 220.3-221.9 feet; elevation on top of coal
 is 6820 feet



UPPER CARBON NO. 6 (76-6)

Thickness of bed: 2.3'

Thickness sampled: 2.3'

LOWER CARBON NO. 6 (76-7)

Thickness of bed: 1.6'

Thickness sampled: 1.6'

Figure 8. Megascopic descriptions of the Upper and Lower Carbon No. 6 coals from Core Hole WGS-C1 (Sample Nos. 76-6 and 76-7)

SAMPLE NO. 76-8: Upper Carbon No. 7 (Upper Bench) Coal Bed

CORE HOLE: WGS-C1

STATE: Wyoming

GEOLOGIC FORMATION: Hanna

COUNTY: Carbon

AGE: Paleocene

SECTION: 34

COAL FIELD: Hanna

TOWNSHIP: 22N.

COAL-BEARING AREA: Hanna

RANGE: 80W.

QUADRANGLE: Carbon



COAL DESCRIPTION: See Figure 9

THICKNESS OF COAL (FEET): 4.0

THICKNESS SAMPLED (FEET): 1.75

CONDITION OF SAMPLE: Unbroken

TYPE OF SAMPLE: Core

DATE OF SAMPLING: September 26, 1976

SAMPLE COLLECTOR: Wyoming Geological Survey

LABORATORY NUMBERS:

Wyoming Geological Survey 76-8

U.S. Bureau of Mines K72363

U.S. Geological Survey D188044

MISCELLANEOUS COMMENTS:

Core hole interval 273.8-275.55 feet; elevation on top of coal
is 6766 feet

SAMPLE NO. 76-9: Upper Carbon No. 7 (Lower Bench) Coal Bed

CORE HOLE: WGS-C1	STATE: Wyoming
GEOLOGIC FORMATION: Hanna	COUNTY: Carbon
AGE: Paleocene	SECTION: 34
COAL FIELD: Hanna	TOWNSHIP: 22N.
COAL-BEARING AREA: Hanna	RANGE: 80W.
	QUADRANGLE: Carbon



COAL DESCRIPTION: See Figure 9
THICKNESS OF COAL (FEET): 4.0
THICKNESS SAMPLED (FEET): 1.9
CONDITION OF SAMPLE: Partially broken and jumbled
TYPE OF SAMPLE: Core

DATE OF SAMPLING: September 26, 1976
SAMPLE COLLECTOR: Wyoming Geological Survey
LABORATORY NUMBERS:

Wyoming Geological Survey	76-9
U.S. Bureau of Mines	K72364
U.S. Geological Survey	D188045

MISCELLANEOUS COMMENTS:

Core hole interval 275.9-277.8 feet; elevation on top of coal
is 6764 feet

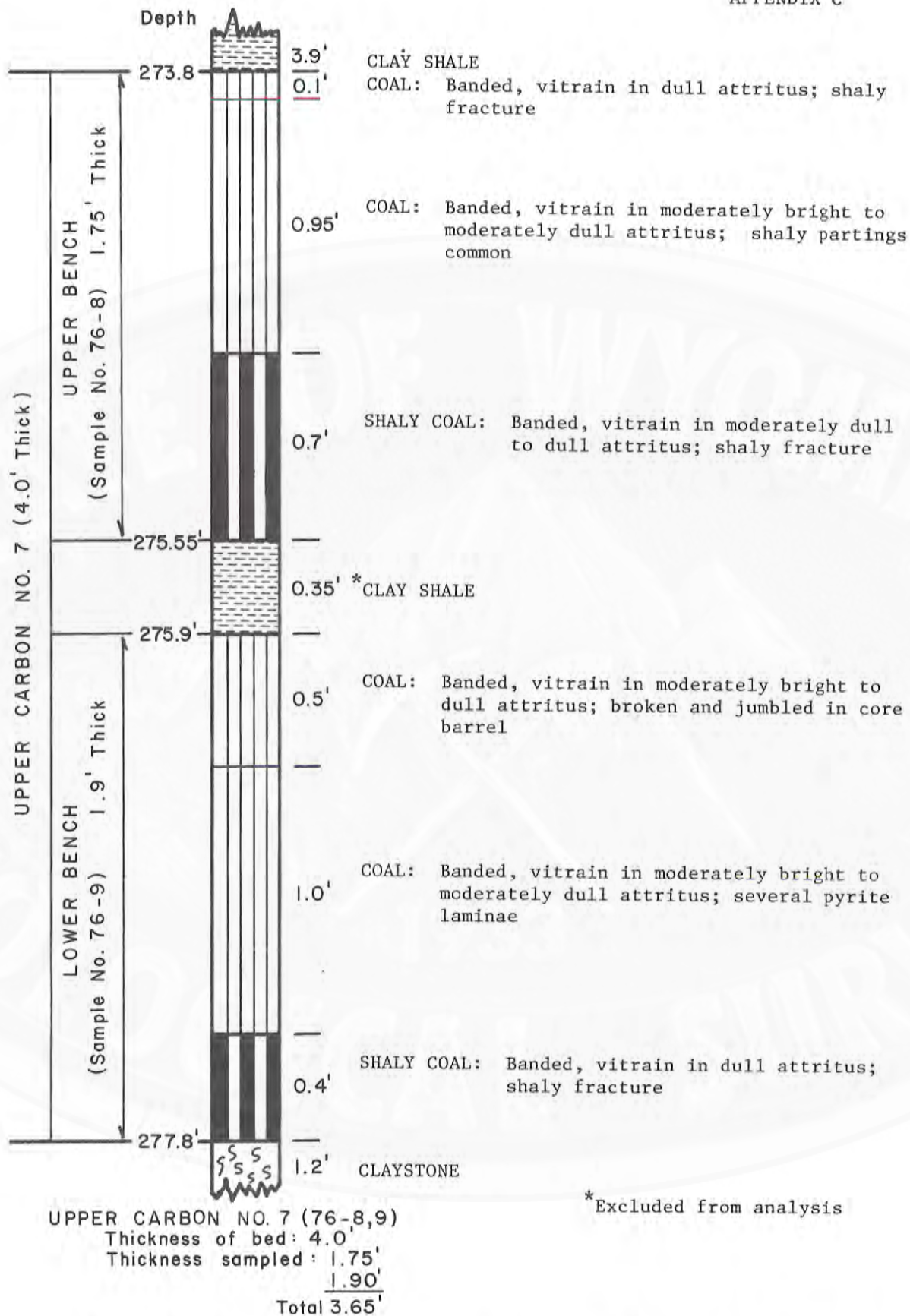
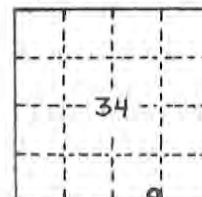


Figure 9. Megascopic descriptions of the upper and lower benches of the Upper Carbon No. 7 coal from Core Hole WGS-C1 (Sample Nos. 76-8 and 76-9)

SAMPLE NO. 76-10: Lower Carbon No. 7 Coal Bed

CORE HOLE: WGS-C1	STATE: Wyoming
GEOLOGIC FORMATION: Hanna	COUNTY: Carbon
AGE: Paleocene	SECTION: 34
COAL FIELD: Hanna	TOWNSHIP: 22N.
COAL-BEARING AREA: Hanna	RANGE: 80W.
	QUADRANGLE: Carbon



COAL DESCRIPTION: See Figure 10
THICKNESS OF COAL (FEET): 1.3
THICKNESS SAMPLED (FEET): 1.3
CONDITION OF SAMPLE: Unbroken
TYPE OF SAMPLE: Core

DATE OF SMAPLING : October 14, 1976

SAMPLE COLLECTOR: Wyoming Geological Survey

LABORATORY NUMBERS:

Wyoming Geological Survey	76-10
U.S. Bureau of Mines	K72365
U.S. Geological Survey	D188046

MISCELLANEOUS COMMENTS:

Core hole interval 294.3-295.6 feet; elevation on top of coal
is 6746 feet

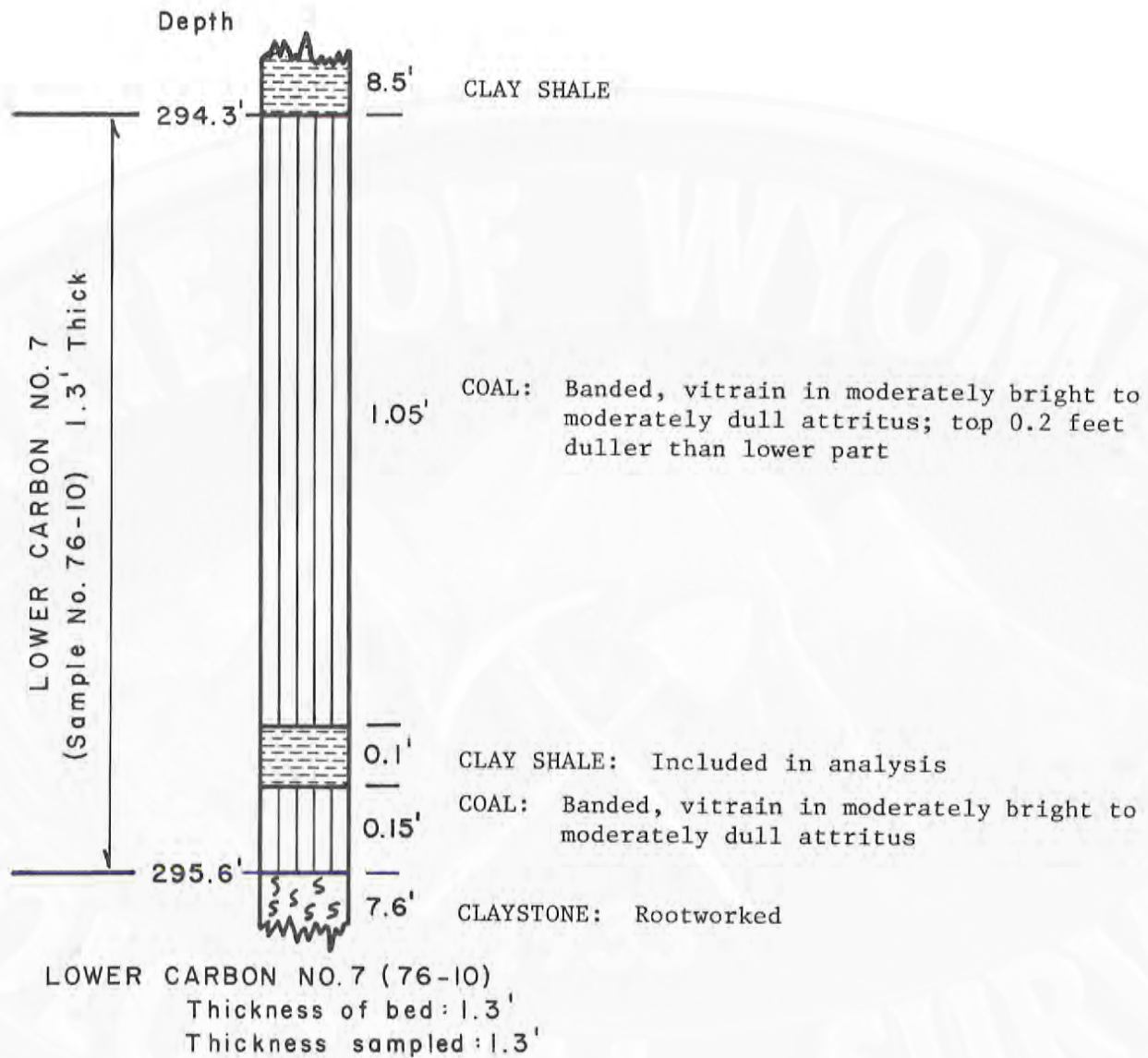


Figure 10. Megascopic description of the Lower Carbon No. 7 coal from Core Hole WGS-C1 (Sample No. 76-10)

SAMPLE NO. 76-11: Bed No. 111 Coal

CORE HOLE: WGS-C1	STATE: Wyoming
GEOLOGIC FORMATION: Hanna	COUNTY: Carbon
AGE: Paleocene	SECTION: 34
COAL FIELD: Hanna	TOWNSHIP: 22N.
COAL-BEARING AREA: Hanna	RANGE: 80W.
	QUADRANGLE: Carbon



COAL DESCRIPTION: See Figure 11
THICKNESS OF COAL (FEET): 4.3
THICKNESS SAMPLED (FEET): 4.3
CONDITION OF SAMPLE: Jumbled in core barrel; some loss
TYPE OF SAMPLE: Core

DATE OF SAMPLING: October 23, 1976
SAMPLE COLLECTOR: Wyoming Geological Survey
LABORATORY NUMBERS:

Wyoming Geological Survey	76-11
U.S. Bureau of Mines	K72366
U.S. Geological Survey	D188047

MISCELLANEOUS COMMENTS:

Core hole interval 488.7-493.0 feet; elevation on top of coal
is 6551 feet

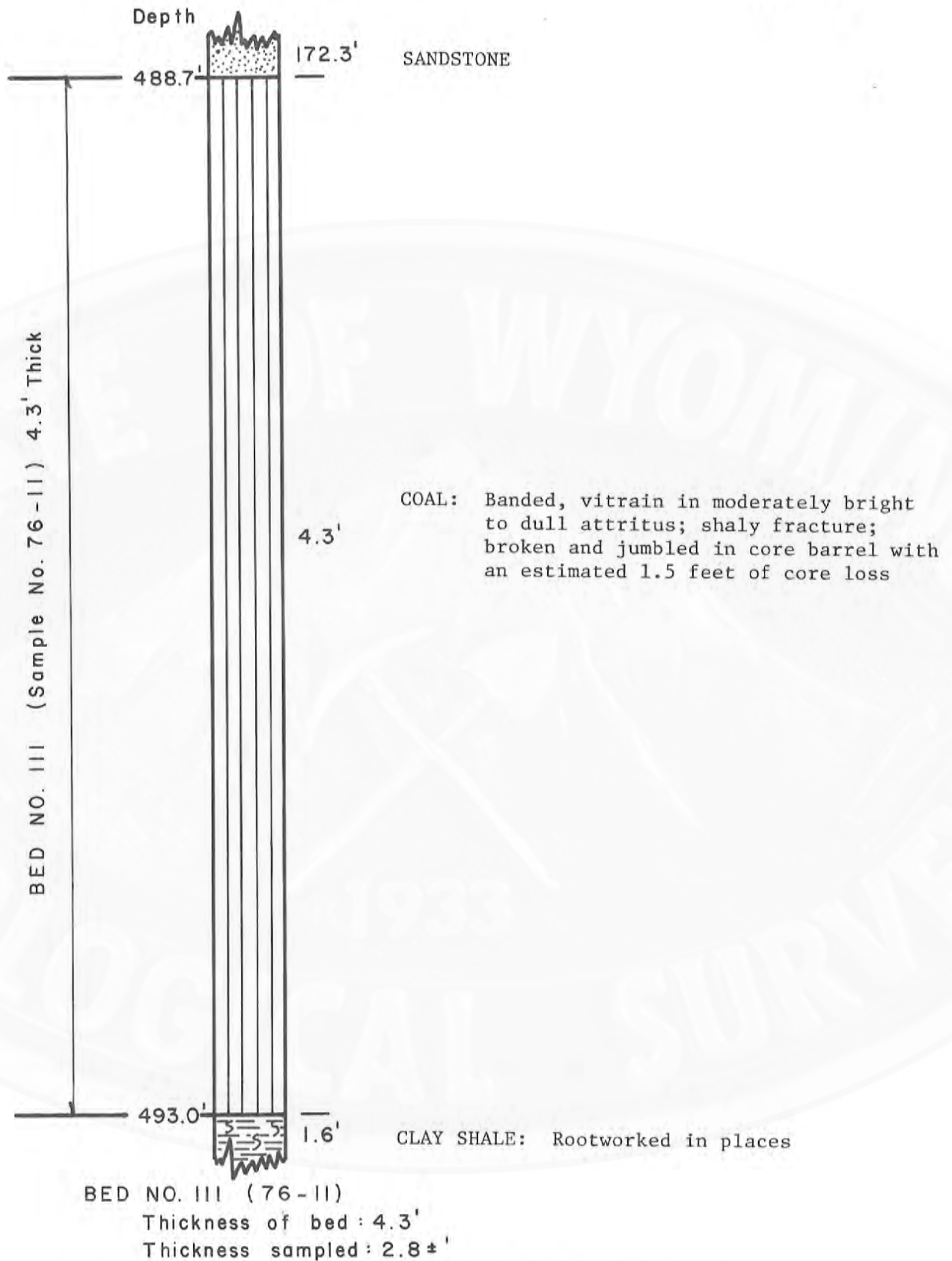


Figure 11. Megascopic description of Bed No. 111 from Core Hole WGS-C1 (Sample No. 76-11)

SAMPLE NO. 76-12: Upper Bed No. 109 Coal

CORE HOLE: WGS-C2

GEOLOGIC FORMATION: Hanna

AGE: Paleocene

COAL FIELD: Hanna

COAL-BEARING AREA: Hanna

STATE: Wyoming

COUNTY: Carbon

SECTION: 24

TOWNSHIP: 21N.

RANGE: 80W.

QUADRANGLE: Halfway Hill



COAL DESCRIPTION: See Figure 12

THICKNESS OF COAL (FEET): 7.2

THICKNESS SAMPLED (FEET): 5.8

CONDITION OF SAMPLE: Unbroken

TYPE OF SAMPLE: Core

DATE OF SAMPLING: November 24, 1976

SAMPLE COLLECTOR: Wyoming Geological Survey

LABORATORY NUMBERS:

Wyoming Geological Survey 76-12

U.S. Bureau of Mines K72367

U.S. Geological Survey D188048

MISCELLANEOUS COMMENTS:

Core hole interval 100.9-108.1 feet; elevation on top of coal
is 7049 feet

SAMPLE NO. 76-13: Lower Bed No. 109 Coal

CORE HOLE: WGS-C2	STATE: Wyoming
GEOLOGIC FORMATION: Hanna	COUNTY: Carbon
AGE: Paleocene	SECTION: 24
COAL FIELD: Hanna	TOWNSHIP: 21N.
COAL-BEARING AREA: Hanna	RANGE: 80W.
	QUADRANGLE: Halfway Hill



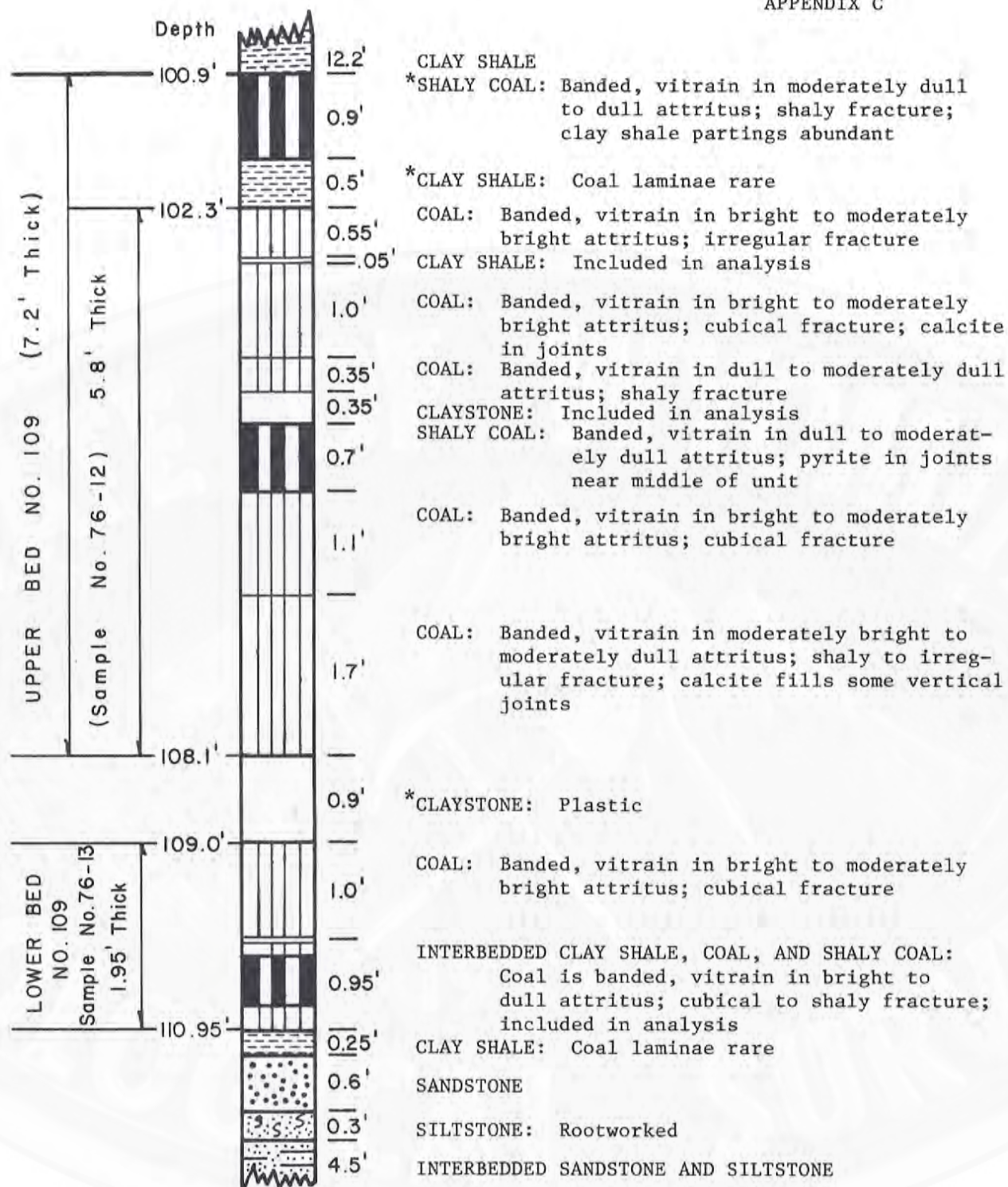
COAL DESCRIPTION: See Figure 12
THICKNESS OF COAL (FEET): 1.95
THICKNESS SAMPLED (FEET): 1.95
CONDITION OF SAMPLE: Unbroken
TYPE OF SAMPLE: Core

DATE OF SAMPLING: November 24, 1976
SAMPLE COLLECTOR: Wyoming Geological Survey
LABORATORY NUMBERS:

Wyoming Geological Survey	76-13
U.S. Bureau of Mines	K72368
U.S. Geological Survey	D188049

MISCELLANEOUS COMMENTS:

Core hole interval 109.0-110.95 feet; elevation of top of coal
is 7041



UPPER BED NO. 109 (76-12)

Thickness of bed: 7.2'

Thickness sampled: 5.8'

*Excluded from analysis

LOWER BED NO. 109 (76-13)

Thickness of bed: 2.0'

Thickness sampled: 2.0'

Figure 12. Megascopic descriptions of the Upper and Lower Bed No. 109 coals from Core Hole WGS-C2 (Sample Nos. 76-12 and 76-13)

SAMPLE NO. 76-14: Upper Carbon No. 6 Coal Bed

CORE HOLE: WGS-C3

STATE: Wyoming

GEOLOGIC FORMATION: Hanna

COUNTY: Carbon

AGE: Paleocene

SECTION: 35

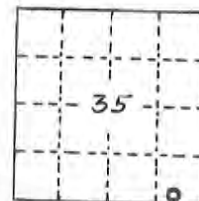
COAL FIELD: Hanna

TOWNSHIP: 22N.

COAL-BEARING AREA: Hanna

RANGE: 80W.

QUADRANGLE: Halfway Hill



COAL DESCRIPTION: See Figure 13

THICKNESS OF COAL (FEET): 6.2

THICKNESS SAMPLED (FEET): 6.2

CONDITION OF SAMPLE: Broken in places

TYPE OF SAMPLE: Core

DATE OF SAMPLING: November 5, 1976

SAMPLE COLLECTOR: Wyoming Geological Survey

LABORATORY NUMBERS:

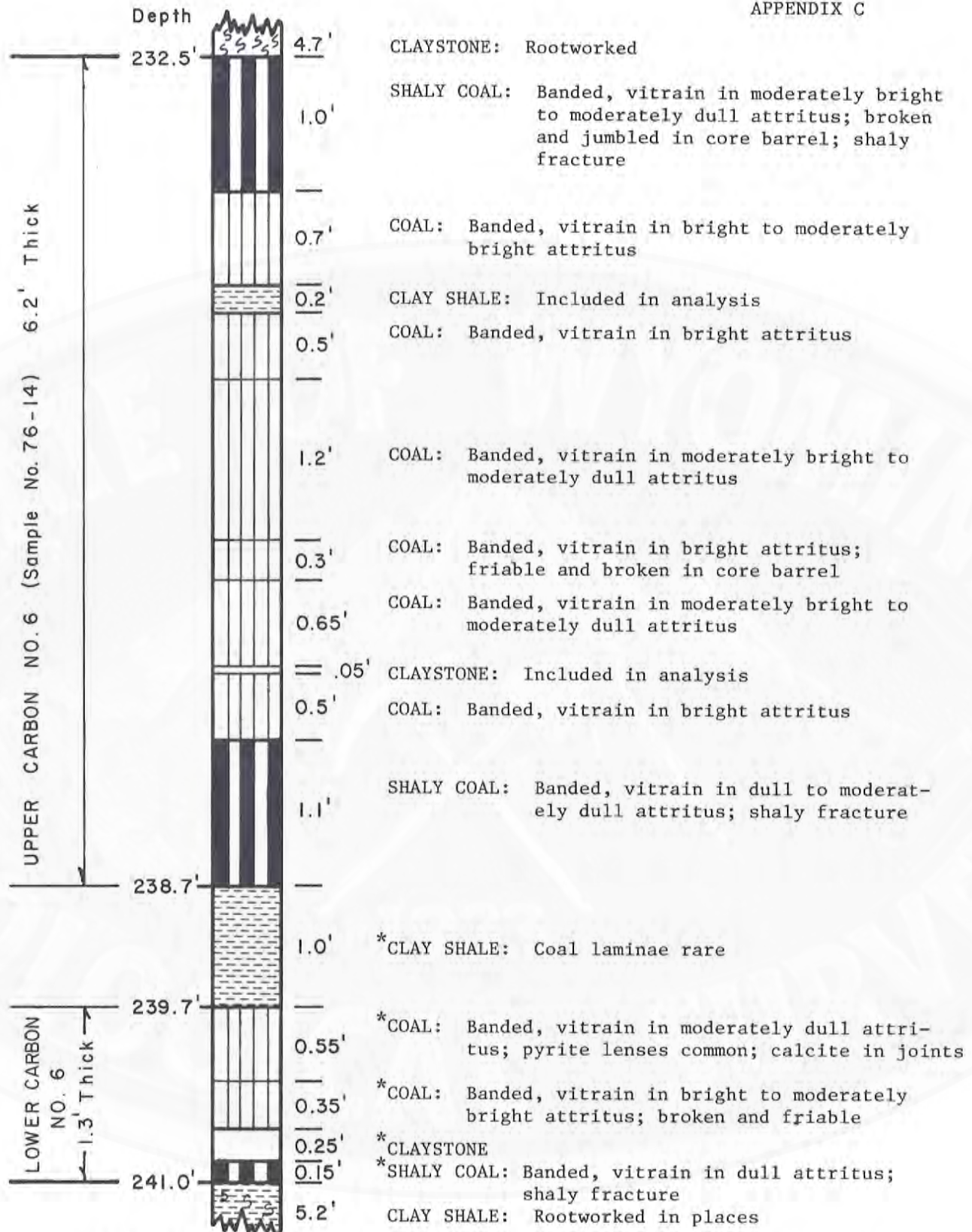
Wyoming Geological Survey 76-14

U.S. Bureau of Mines K72369

U.S. Geological Survey D188050

MISCELLANEOUS COMMENTS:

Core hole interval 232.5-238.7 feet; elevation on top of coal
is 6717 feet



UPPER CARBON NO. 6 (76-14)

Thickness of bed: 6.2'

Thickness sampled: 6.2'

*Excluded from analysis

Figure 13. Megascopic descriptions of the Upper Carbon No. 6 coal (Sample No. 76-14) and the Lower Carbon No. 6 coal from Core Hole WGS-C3

SAMPLE NO. 76-15: Upper Carbon No. 7 (Upper Bench) Coal Bed

CORE HOLE: WGS-C3

STATE: Wyoming

GEOLOGIC FORMATION: Hanna

COUNTY: Carbon

AGE: Paleocene

SECTION: 35

COAL FIELD: Hanna

TOWNSHIP: 22N.

COAL-BEARING AREA: Hanna

RANGE: 80W.

QUADRANGLE: Halfway Hill



COAL DESCRIPTION: See Figure 14

THICKNESS OF COAL (FEET): 4.3

THICKNESS SAMPLED (FEET): 1.7

CONDITION OF SAMPLE: Loose and friable in places

TYPE OF SAMPLE: Core

DATE OF SAMPLING: November 8, 1976

SAMPLE COLLECTOR: Wyoming Geological Survey

LABORATORY NUMBERS:

Wyoming Geological Survey 76-15

U.S. Bureau of Mines K72370

U.S. Geological Survey D188051

MISCELLANEOUS COMMENTS:

Core hole interval 268.1-269.8 feet; elevation on top of coal
is 6682 feet

SAMPLE NO. 76-16: Upper Carbon No. 7 (lower bench) Coal Bed

CORE HOLE: WGS-C3

STATE: Wyoming

GEOLOGIC FORMATION: Hanna

COUNTY: Carbon

AGE: Paleocene

SECTION: 35

COAL FIELD: Hanna

TOWNSHIP: 22N.

COAL-BEARING AREA: Hanna

RANGE: 80W.

QUADRANGLE: Halfway Hill



COAL DESCRIPTION: See Figure 14

THICKNESS OF COAL (FEET): 4.3

THICKNESS SAMPLED (FEET): 1.7

CONDITION OF SAMPLE: Unbroken

TYPE OF SAMPLE: Core

DATE OF SAMPLING: November 8, 1976

SAMPLE COLLECTOR: Wyoming Geological Survey

LABORATORY NUMBERS:

Wyoming Geological Survey 76-16

U.S. Bureau of Mines K72371

U.S. Geological Survey D188052

MISCELLANEOUS COMMENTS:

Core hole interval 270.3-272.0 feet; elevation on top of coal
is 6680 feet

SAMPLE NO. 76-17: Lower Carbon No. 7 Coal Bed

CORE HOLE: WGS-C3

STATE: Wyoming

GEOLOGIC FORMATION: Hanna

COUNTY: Carbon

AGE: Paleocene

SECTION: 35

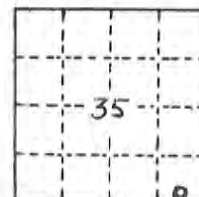
COAL FIELD: Hanna

TOWNSHIP: 22N.

COAL-BEARING AREA: Hanna

RANGE: 80W.

QUADRANGLE: Halfway Hill



COAL DESCRIPTION: See Figure 14

THICKNESS OF COAL (FEET): 2.0

THICKNESS SAMPLED (FEET): 2.0

CONDITION OF SAMPLE: Jumbled and broken at bottom

TYPE OF SAMPLE: Core

DATE OF SAMPLING: November 8, 1976

SAMPLE COLLECTOR: Wyoming Geological Survey

LABORATORY NUMBERS:

Wyoming Geological Survey 76-17

U.S. Bureau of Mines K72372

U.S. Geological Survey D188053

MISCELLANEOUS COMMENTS:

Core hole interval 283.2-285.2 feet; elevation on top of coal
is 6667 feet

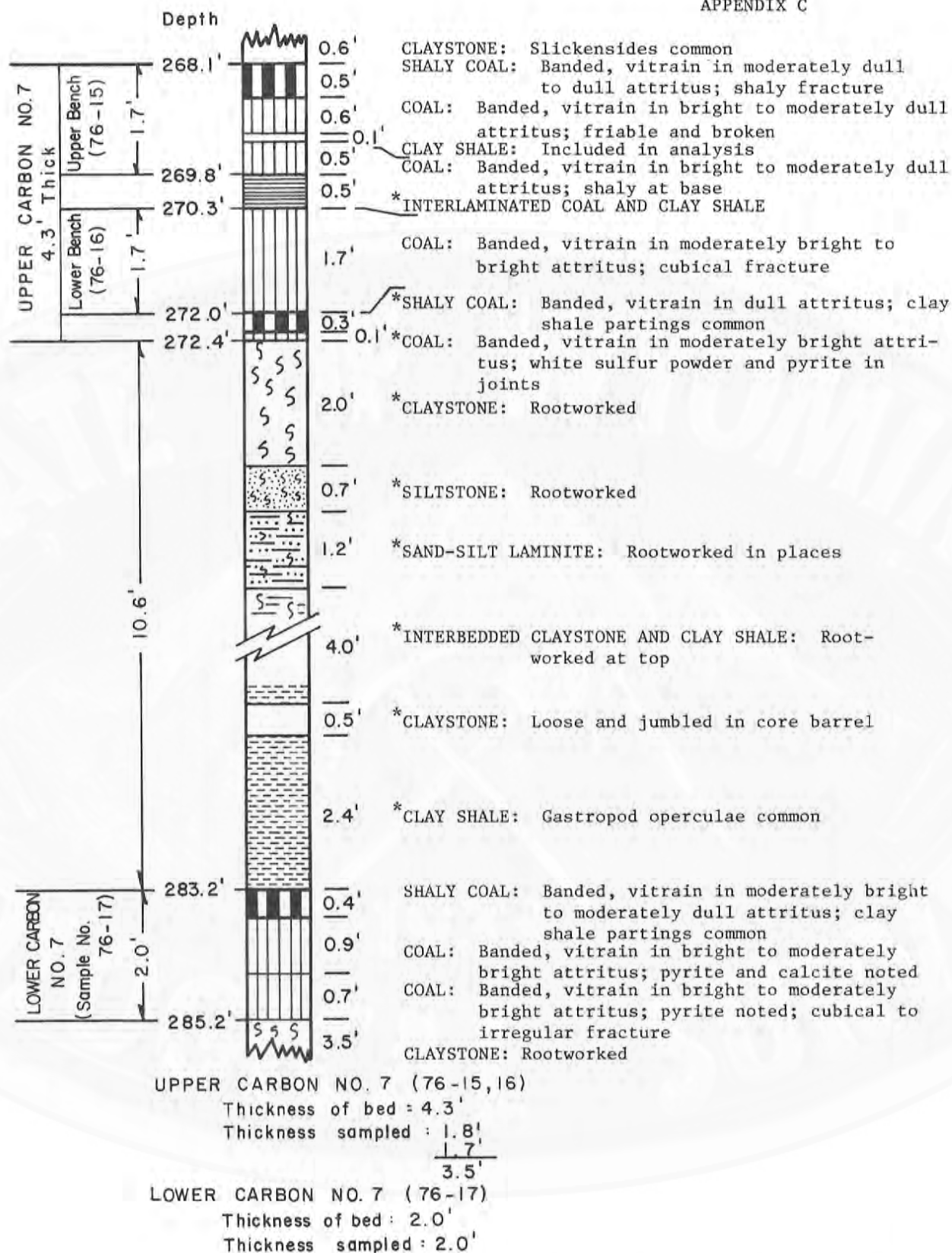


Figure 14. Megascopic descriptions of the upper and lower benches of the Upper Carbon No. 7 coal (Sample Nos. 76-15 and 76-16) and the Lower Carbon No. 7 coal (Sample No. 76-17) from Core Hole WGS-C3

SAMPLE NO. 76-18: Bed No. 111 Coal

CORE HOLE: WGS-C3

STATE: Wyoming

GEOLOGIC FORMATION: Hanna

COUNTY: Carbon

AGE: Paleocene

SECTION: 35

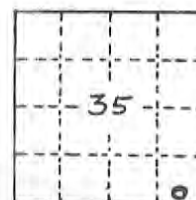
COAL FIELD: Hanna

TOWNSHIP: 22N.

COAL-BEARING AREA: Hanna

RANGE: 80W.

QUADRANGLE: Halfway Hill



COAL DESCRIPTION: See Figure 15

THICKNESS OF COAL (FEET): 3.4

THICKNESS SAMPLED (FEET): 3.4

CONDITION OF SAMPLE: Unbroken

TYPE OF SAMPLE: Core

DATE OF SAMPLING: November 12, 1976

SAMPLE COLLECTOR: Wyoming Geological Survey

LABORATORY NUMBERS:

Wyoming Geological Survey 76-18

U.S. Bureau of Mines K72373

U.S. Geological Survey D188054

MISCELLANEOUS COMMENTS:

Core hole interval 448.6-452.0 feet; elevation on top of coal
is 6501 feet

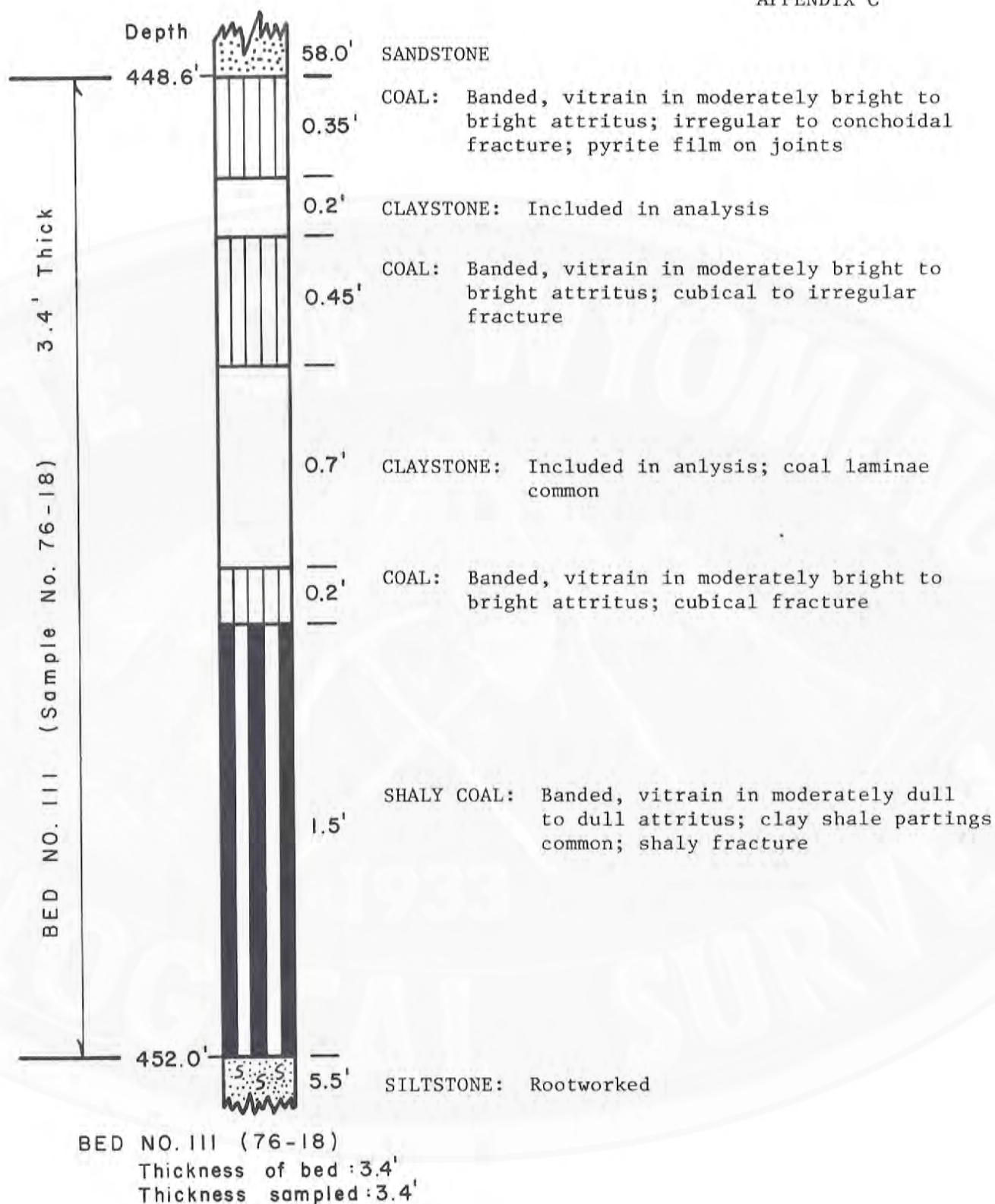
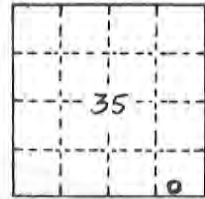


Figure 15. Megascopic description of Bed No. 111 from Core Hole WGS-C3 (Sample No. 76-18)

SAMPLE NO. 76-19: Upper Bed No. 109 Coal

CORE HOLE: WGS-C3	STATE: Wyoming
GEOLOGIC FORMATION: Hanna	COUNTY: Carbon
AGE: Paleocene	SECTION: 35
COAL FIELD: Hanna	TOWNSHIP: 22N.
COAL-BEARING AREA: Hanna	RANGE: 80W.
	QUADRANGLE: Halfway Hill



COAL DESCRIPTION: See Figure 16
THICKNESS OF COAL (FEET): 3.8
THICKNESS SAMPLED (FEET): 3.8
CONDITION OF SAMPLE: Unbroken
TYPE OF SAMPLE: Core

DATE OF SAMPLING: November 14, 1976
SAMPLE COLLECTOR: Wyoming Geological Survey
LABORATORY NUMBERS:

Wyoming Geological Survey	76-19
U.S. Bureau of Mines	K72374
U.S. Geological Survey	D188055

MISCELLANEOUS COMMENTS:

Core hole interval 566.8-570.6 feet; elevation on top of coal
is 6383 feet

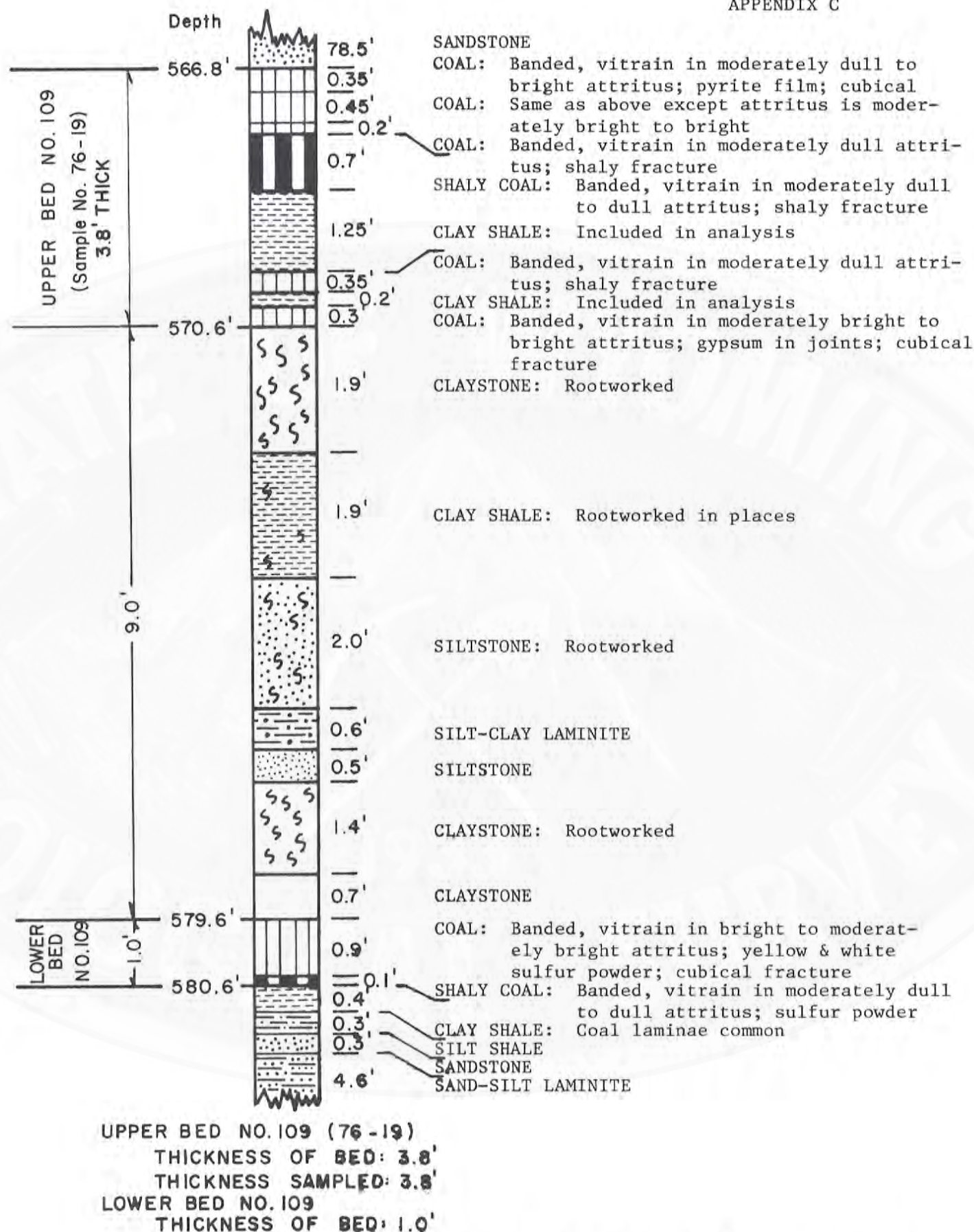


Figure 16. Megascopic descriptions of the Upper (Sample No. 76-19) and Lower Bed No. 109 coals from Core Hole WGS-C3

SAMPLE NO. 77-1: Carbon No. 6 Rider Coal Bed

CORE HOLE: WGS-C4

GEOLOGIC FORMATION: Hanna

AGE: Paleocene

COAL FIELD: Hanna

COAL-BEARING AREA: Hanna

STATE: Wyoming

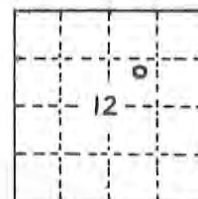
COUNTY: Carbon

SECTION: 12

TOWNSHIP: 21N.

RANGE: 80W.

QUADRANGLE: Halfway Hill



COAL DESCRIPTION: See Figure 17

THICKNESS OF COAL (FEET): 1.95

THICKNESS SAMPLED (FEET): 1.95

CONDITION OF SAMPLE: Unbroken

TYPE OF SAMPLE: Core

DATE OF SAMPLING: June 19, 1977

SAMPLE COLLECTOR: Wyoming Geological Survey

LABORATORY NUMBERS:

Wyoming Geological Survey 77-1

U.S. Bureau of Mines --

U.S. Geological Survey D194472

MISCELLANEOUS COMMENTS:

Core hole interval 64.0-65.95 feet; elevation on top of coal
is 6976 feet

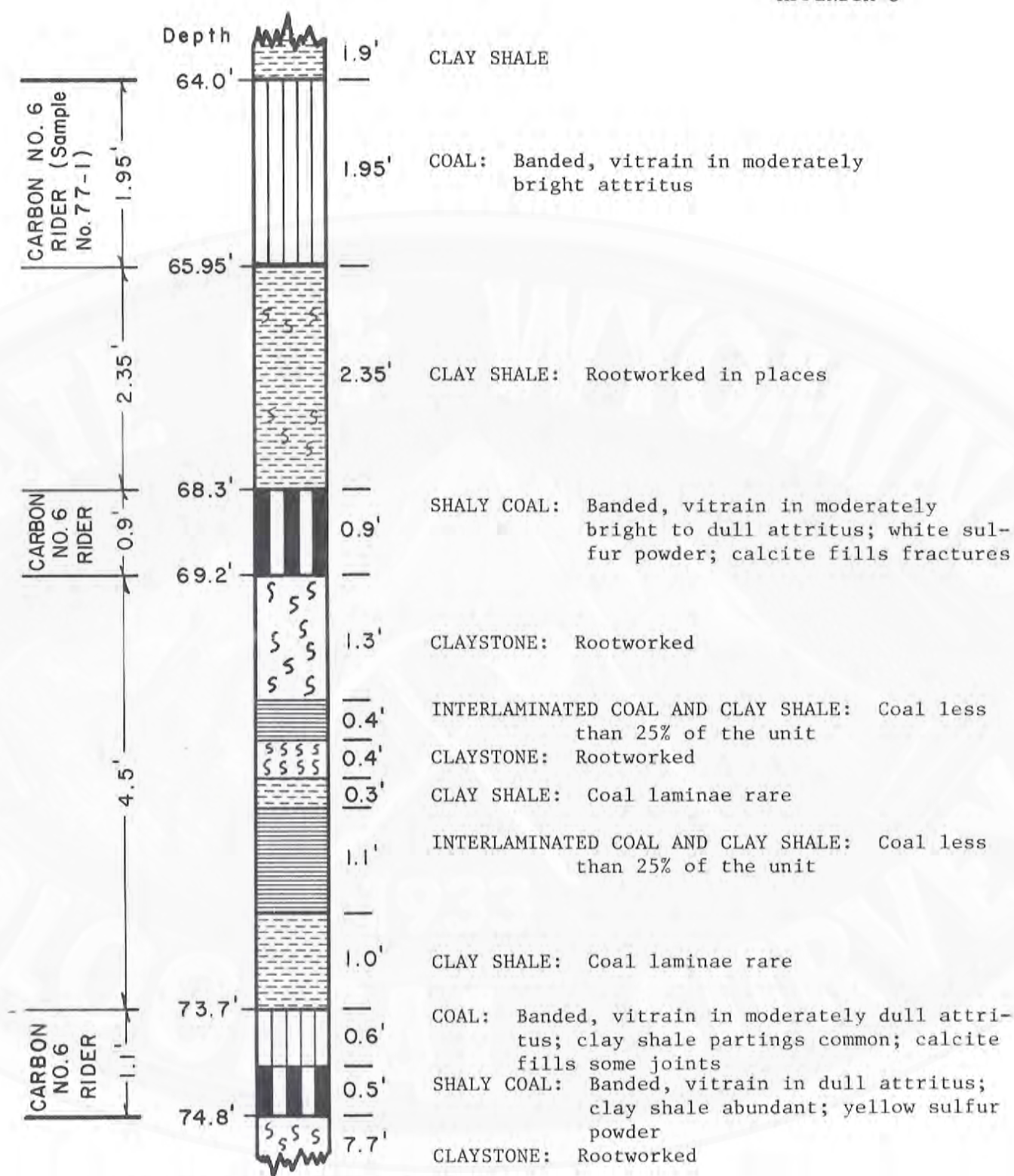


Figure 17. Megascopic descriptions of Carbon No. 6 Rider coals (Sample No. 77-1) from Core Hole WGS-C4

SAMPLE NO. 77-2: Bed No. 111 Coal

CORE HOLE: WGS-C4

STATE: Wyoming

GEOLOGIC FORMATION: Hanna

COUNTY: Carbon

AGE: Paleocene

SECTION: 12

COAL FIELD: Hanna

TOWNSHIP: 21N.

COAL-BEARING AREA: Hanna

RANGE: 80W.

QUADRANGLE: Halfway Hill



COAL DESCRIPTION: See Figure 18

THICKNESS OF COAL (FEET): 3.2

THICKNESS SAMPLED (FEET): 3.2

CONDITION OF SAMPLE: Unbroken

TYPE OF SAMPLE: Core

DATE OF SAMPLING: June 23, 1977

SAMPLE COLLECTOR: Wyoming Geological Survey

LABORATORY NUMBERS:

Wyoming Geological Survey 77-2

U.S. Bureau of Mines --

U.S. Geological Survey D194473

MISCELLANEOUS COMMENTS:

Core hole interval 314.4-317.6 feet; elevation on top of coal
is 6726 feet

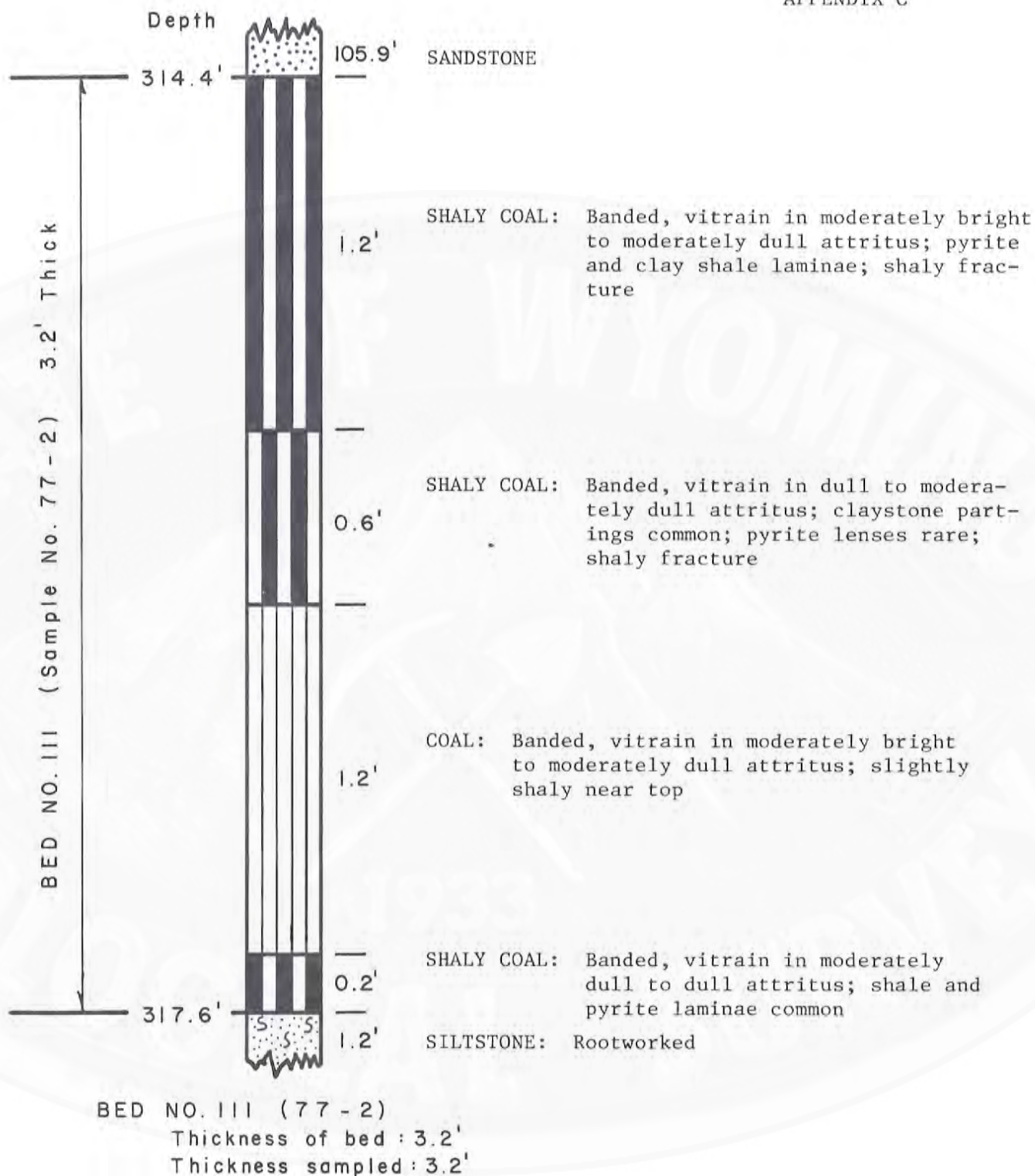
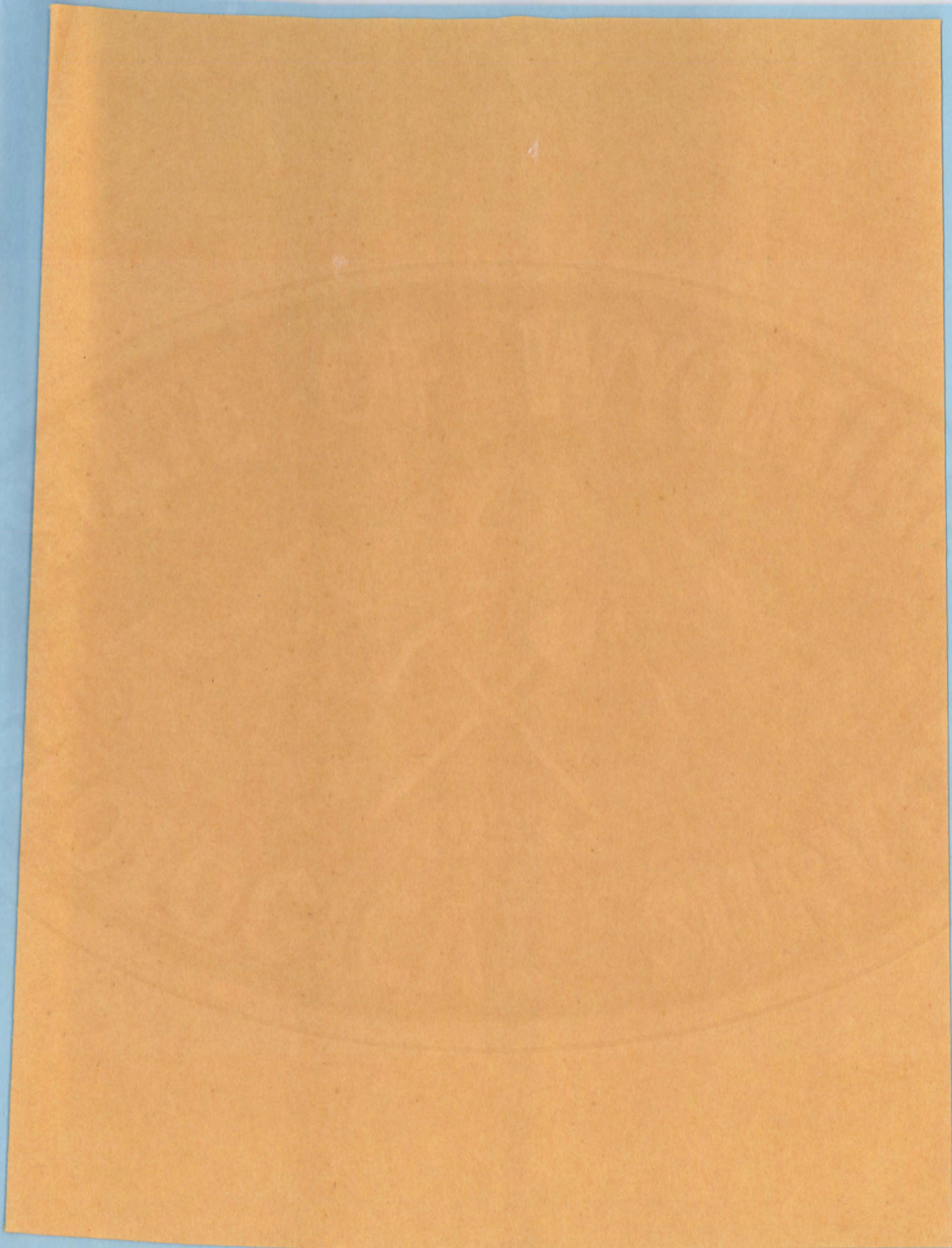


Figure 18. Megascopic description of Bed No. III from Core Hole WGS-C4 (Sample No. 77-2)



REPORTS OF INVESTIGATIONS:RI-16



\$5.00

WSGS-RI16-78