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Chemical Analysis, Physical Property Tests, and Lithologic Description of Cores and Cuttings of Lignite and Overburden Rocks from an Area near Watkins, Colorado

By

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Introduction

The data presented in this report represents analytical and testing information from cores drilled by the Geophysics Department, Colorado School of Mines, assisted by the U.S. Geological Survey. The drilling was done in conjunction with the establishment of a geophysical testing facility by the Colorado School of Mines.

Location of the study area and drill holes is shown in Figure 1. A total of 15 holes were drilled and geophysically logged; holes 9-1 and 7-11 were cored, and attempts to core hole 3-1 were made, but the lignite was very incompetent due to weathering and oxidation and recovery was very poor. Lithologic descriptions of the cores and cuttings for holes 9-1, 7-11, and 3-1 are listed on pages 13-21.

Calculations based on hole 9-1 indicate that of the total lignite zone, 56 percent consists of partings and 44 percent is lignite. These percentages were obtained by statistical analysis of the core description and natural gamma logs of the hole. The total thickness of the lignite zone in hole 9-1 is approximately 18 m.

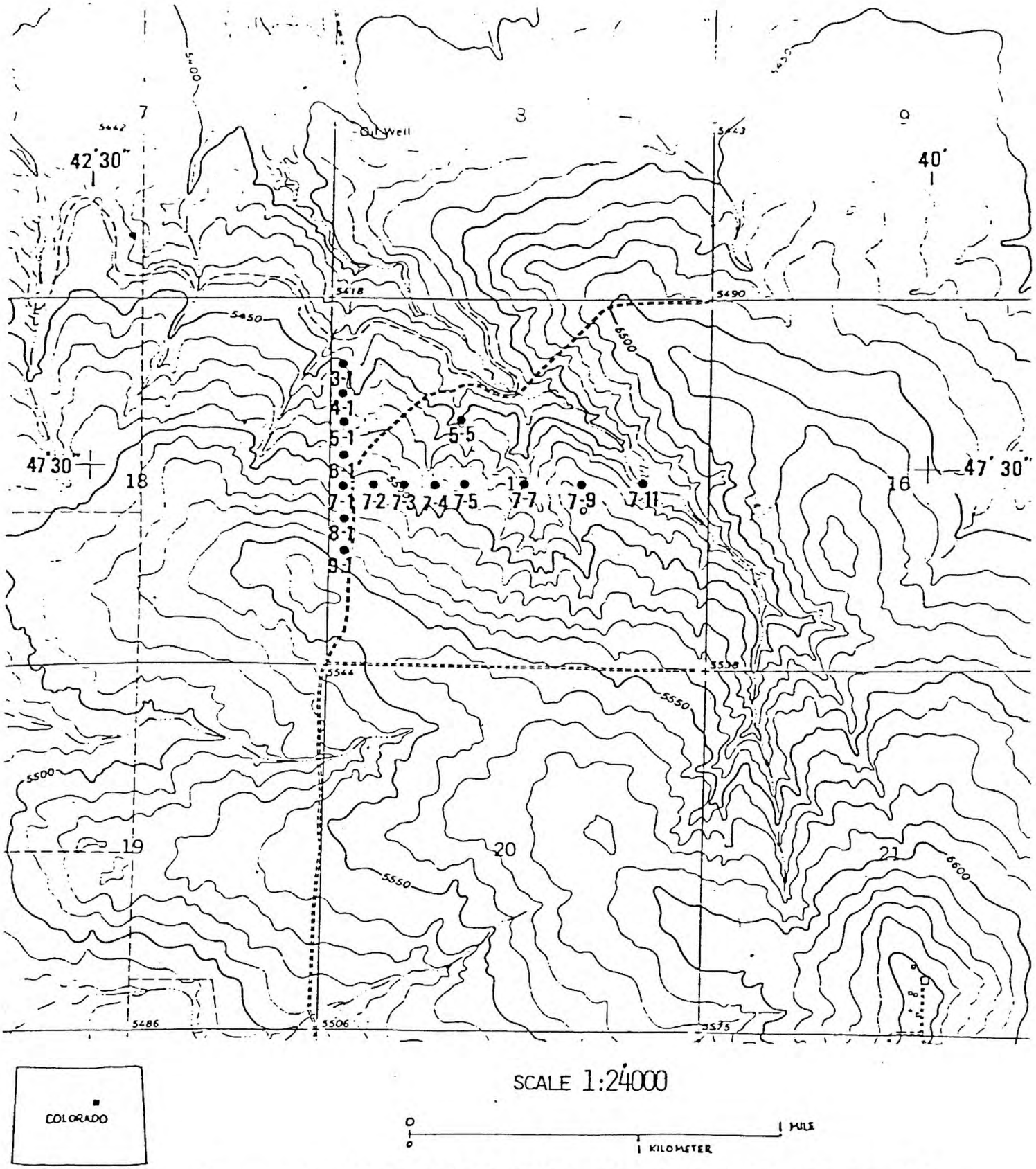

FIGURE 1. LOCATION OF DRILL HOLES IN SEC. 17, T. 3 S., R. 65 W., WATKINS STUDY AREA (ADAPTED FROM BOX ELDER QUADRANGLE)

Regional Geology

Physiographically the Denver basin is in the dissected Colorado Piedmont section of the Great Plains and lies east of the central part of the Front Range. The Denver basin is a broad, gentle, structural and topographic basin whose western margin is characterized by northwest-trending faults and folds, probably formed during the Laramide orogeny.

The study area, which is part of the Scranton District of the Denver coal region as defined by Landis (1959), will be referred to as the Watkins area in this report.

The sedimentary rocks which were drilled are in the Denver Formation and are of Paleocene age (Soister, 1974). They are predominantly gray mudstones with a few interbeds of very fine-grained gray sandstone and lignite. The lignite contains a large number of thin partings, most of which were designated in the core descriptions as thin sandstone beds. Selected samples of these partings were analyzed by petrographic and X-ray diffraction methods and were identified as kaolinitic mudstones (Bohor, personal communication). Bohor studied similar partings in the Denver Formation lignite at an outcrop located 48 kilometers to the south of Watkins area in Elbert County and concluded that these kaolinitic mudstone partings were altered volcanic ash layers (Bohor and others, 1976).

Overview of lignite and overburden analysis

The lignite analytical data are shown on Tables 1, 2, 3, 4, and 7. The rock data is shown on Table 5. Table 6 has been included for comparison of the overburden and lignite compositions with average values for a sandstone, shale, and the earth's crust. Table 7 shows physical property tests on selected intervals of the overburden; these data are for two intervals only as much of the rock was not of sufficient competency to allow testing.

The data shown in the Btu analysis (table 1) on an as-received basis may not be representative of the true heating value of these lignites. Core recovery in the clean lignites was low, and although these values represent the best samples available, they contain a disproportionate amount of non-lignite partings (see Sanchez, 1976).

The inherent quality of these lignites can be more realistically assessed by calculating to a moist, mineral-free Btu value using ASTM D-388-66 (reapproved, 1972) Section 71., Parr formula 3, and using an assumed equilibrium moisture of 32 percent. These values are:

Sample No.	Moist, mineral matter free Btu/lb
D173470	7556
D173471	6709
D173498	6317
D173499	7479

According to Table 1 ASTM D-388, these samples would have an apparent rank of lignite A.

Table 1.--Proximate, ultimate, Btu and forms of sulfur analyses of four lignite samples from hole no. 9-1 and 7-11 of Watkins area, Adams County, Colo.

[All analyses except Btu are in percent. Original moisture content may be slightly more than shown because samples were collected and transported in plastic bags to avoid metal contamination. The samples represent the entire interval of the bed shown. Form of analyses: A, as received; B, moisture-free; C, moisture-and ash-free; D, air-dried. All analyses by Coal Analysis Section, U.S. Bureau of Mines, Pittsburg, Pa.]

Sample No.[1]	Form of analysis	PROXIMATE ANALYSIS				ULTIMATE ANALYSIS							FORMS OF SULFUR		
		Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Ash	Btu value	Sulfate	Pyritic	Organic
D173470	A	35.0	25.8*	25.5	13.7	6.7	36.4	0.6	42.3	0.3	13.7	6,150	0.02	0.07	0.22
	B	----	39.6*	39.4	21.0	4.3	55.9	1.0	17.3	.5	21.0	9,470	.03	.11	.33
	C	----	50.2*	49.8	----	5.5	70.9	1.3	21.7	.6	----	11,990	.03	.15	.42
	D	21.5	31.1*	30.9	16.5	5.8	43.9	.8	32.6	.4	16.5	7,440	----	----	----
D173471	A	28.0	22.7*	17.1	32.2	5.4	27.1	0.5	34.5	0.3	32.2	4,660	0.03	0.06	0.20
	B	----	31.5*	23.8	44.7	3.2	37.6	.7	13.4	.4	44.7	6,470	.05	.08	.28
	C	----	57.0*	43.0	----	5.8	68.0	1.3	24.2	.7	----	11,690	.09	.15	.51
	D	15.0	26.8*	20.2	38.0	4.4	32.0	.6	24.6	.4	38.0	5,500		----	----
D177498	A	27.1	20.7	14.7	37.5	5.0	23.9	0.4	32.9	0.3	37.5	4,050	0.01	0.02	0.26
	B	----	28.4	20.1	51.5	2.8	32.8	.5	12.0	.4	51.5	5,550	.01	.02	.36
	C	----	58.5	41.5	----	5.7	67.6	1.1	24.8	.8	----	11,440	.02	.05	.74
	D	8.4	26.0	18.5	47.1	3.5	30.1	.5	18.4	.4	47.1	5,080	----	----	----
D177499	A	32.9	24.3	25.6	17.2	6.4	35.5	0.6	39.9	0.4	17.2	6,010	0.01	0.02	0.32
	B	----	36.2	38.1	25.7	4.0	52.9	.9	16.0	.5	25.7	8,960	.01	.03	.48
	C	----	48.7	51.3	----	5.4	71.2	1.1	21.6	.7	----	12,060	.02	.05	.64
	D	11.9	31.9	33.6	22.6	4.9	46.6	.8	24.6	.5	22.6	7,890	----	----	----

D177498 Fusibility of Ash, temp. °F Initial Deform 2800 Softening 2840 Fluid 2880
D177499 Fusibility of Ash, temp. °F Initial Deform 2530 Softening 2580 Fluid 2630

[1]Sample number represents the following footages: D173470 - 159.46'-170.86'(hole 9-1)
D173471 - Composite of the intervals 146.87'-159.46', 170.86'-178.00' (hole 9-1)
D177498 - Composite of the intervals 47'-48', 49'-50.3' (hole 7-11)
D177499 - 60' to 70' (composite of intervals 60.0'-61.8', 62.3'-63.8', 63.8'-66.0', 68.3'-70') hole 7-11.

* Determined by modified method

Table 2.--Major and minor oxide and trace element composition of the laboratory ash of four lignite samples from hole no. 9-1 and 7-11 of Watkins area, Adams County, Colo.

[Values are in either percent or parts per million. The coals were ashed at 525°C. L after a value means less than the value shown, and N means not detected. (XRF) = X-Ray Florescence Analysis, (A) = determined by Atomic Absorption, and S after the element title means that the values listed were determined by semiquantitative spectrographic analysis. The spectrographic results are to be identified with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, etc., but are reported arbitrarily as mid-points of those brackets, 1.0, 0.7, 0.5, 0.3, 0.20, 0.15, 0.1, etc. The precision of the spectrographic data is approximately plus or minus one bracket at 68 percent, or two brackets at 95 percent confidence.]

Sample No.[1]	Ash %	Al_2O_3 % (XRF)	CaO % (XRF)	Fe_2O_3 % (XRF)	MgO % (A)	Na_2O % (A)	K_2O % (XRF)	SO_3 % (XRF)	SiO_2 % (XRF)	Cl % (XRF)
D173470	16.9	23	14	3.3	0.65	0.76	0.4	1.5	25	0.1 L
D173471	39.1	29	5.0	1.9	.56	.67	1.5	.52	39	.1 L
D177498	51.4	28	3.9	2.7	.5	.42	1.6	1.3	55	.1 L
D177499	25.9	31	12	2.4	.3	.61	.65	3.8	41	.1 L

Sample No.[1]	MnO %	P_2O_5 % (XRF)	TiO_2 % (XRF)	Cd ppm (A)	Cu ppm (A)	Li ppm (A)	Pb ppm (A)	Zn ppm (A)	B ppm-s	Ba ppm-s
D173470	0.020 L (XRF)	1.1	1.2	1 L	122	62	35	44	200	3000
D173471	.020 L (XRF)	.18	1.4	1 L	80	87	35	106	70	700
D177498	.013 (A)	.24	.99	1 L	89	71	40	71	50	700
D177499	.041 (A)	.50	1.5	1 L	89	104	30	63	150	1000

Sample No.[1]	Be ppm-s	Co ppm-s	Cr ppm-s	Ga ppm-s	Ge ppm-s	La ppm-s	Mo ppm-s	Nb ppm-s	Nd ppm-s	Ni ppm-s
D173470	5	15	20	30	N	100	15	15	150 L	15
D173471	5	20	15	30	N	100	N	N	150	10 L
D177498	3	10	50	30	N	100	N	20	N	10
D177499	N	15	15	30	N	150 L	7	20	150 L	10 L

Sample No.[1]	Sc ppm-s	Sr ppm-s	V ppm-s	Y ppm-s	Yb ppm-s	Zr ppm-s
D173470	20	5000	150	50	5	200
D173471	30	700	300	30	5	200
D177498	20	300	200	50	5	300
D177499	30	700	300	70	5	300

[1]Sample numbers represent the following footages: D173470 - 159.46'-170.86' (Hole 9-1)
D173471 - Composite of the intervals 146.87'-159.46', 170.86'-178.00' (Hole 9-1)
D177498 - Composite of the intervals 47'-48', 49'-50.3' (Hole 7-11)
D177499 - 60.0'-70.0' (Composite of intervals 60.0'-61.8', 62.3'-63.8', 63.8'-66.0', 68.3'-70') hole 7-11

Table 3.--Content of seven trace elements in four lignite samples from holes No. 9-1 and 7-11 of the Watkins area, Adams County, Colo.

[Analyses on air-dried (32°C) coal. All values are in parts per million. N means not detected]

Sample	As	F	Hg	Sb	Sc	Th	U
D173470	1	120	0.12	0.1	2.3	6.3	1.2
D173471	1	190	.10	.3	2.8	8.1	2.3
D177498	1	325	.15	.4	4.1	13.5	N
D177499	.5	95	.10	.3	3.1	4.5	N

[1]Sample numbers represent the following footages:
D173470 - 159.46'-170.86' (hole 9-1)
D173471 - Composite of the intervals 146.87'-159.46', 170.86'-178.00' (hole 9-1)
D177498 - Compsite of the intervals 47'-48', 49'-50.3' (hole 7-11)
D177499 - 60' to 70' (Composite of intervals 60.0'-61.8', 62.3'-63.8' 63.8'-66.0', 68.3'-70') hole 7-11

Table 4.--Major, minor, and trace element composition of four lignite samples from hole no. 9-1 and 7-11, Watkins area, Adams County, Colo., reported on whole-coal basis

[Values are in either percent or parts per million. Al, Ca, Fe, Mg, Na, K, Si, Cl, Mn, P, Ti, Cd, Cu, Li, Pb, and Zn values were calculated from analyses of ash. As, F, Hg, Sb, Se, Th, and U values are from direct determinations on air-dried (32°C) coal. The remaining analyses were calculated from spectrographic determinations on ash. L after a value means less than the value shown, and N means not detected.]

SAMPLE	Si%	Al%	Ca%	Mg%	Na%	K%	Fe%	Mn ppm	Ti%	P ppm
D173470	2.0	2.1	1.7	0.066	0.095	0.057	0.39	26 L	0.12	788
D173471	7.2	5.9	1.4	.13	.20	.50	.51	61 L	.33	318
D177498	6.0	7.6	1.4	.15	.15	.17	.97	51	.30	540
D177499	5.0	8.0	3.1	.04	.11	.14	.43	83	.23	570

SAMPLE	Cl%	As ppm	Cd ppm	Cu ppm	F ppm	Hg ppm	Li ppm	Pb ppm	Sb ppm	Se ppm
D173470	0.017L	1	0.2L	20.6	120	0.12	10.5	5.9	0.1	2.3
D173471	.039L	1	.4L	31.3	190	.10	34.0	13.7	.3	2.8
D177498	.051L	1	.5L	45.7	167	.08	36.5	20.6	.4	2.1
D177499	.026L	.5	.3L	23.0	25	.03	36.9	7.8	.3	.80

SAMPLE	Th ppm	U ppm	Zn ppm	B ppm-s	Ba ppm-s	Be ppm-s	Co ppm-s	Cr ppm-s	Ga ppm-s	Ge ppm-s
D173470	6.3	1.2	7.4	30	500	0.7	2	3	5	N
D173471	8.1	2.3	41.4	30	300	2	7	7	10	N
D177498	13.5	3.0	36.5	20	300	1.5	5	20	15	N
D177499	4.5	1.5	16.3	50	200	N	5	3	7	N

SAMPLE	La ppm -s	Mo ppm-s	Nb ppm-s	Nd ppm-s	Ni ppm-s	Sc ppm-s	Sr ppm-s	V ppm-s	Y ppm-s	Yb ppm-s
D173470	15	2	5	20 L	2	3	700	20	7	0.7
D173471	50	N	10	70	5 L	10	300	100	10	2
D177498	50	N	10	N	5	10	150	100	20	20
D177499	50	1.5	5	50	20	7	200	70	15	15

SAMPLE	Zr ppm-s
D173470	30
D173471	70
D177498	150
D177499	70

Sample numbers represent the following footages: D173470 - 159.46'-170.86' (hole 9-1)
D173471 - Composite of the intervals 146.87'-159.46', 170.86'-178.00' (hole 9-1)
D177498 - Composite of the intervals 47'-48', 49'-50.3' (hole 7-11)
D177499 - 60.0'-70.0' (composite of intervals 60.0'-61.8', 62.3'-63.8', 63.8'-66.0', 68.3'-70') hole 7-11

Table 5.--Major and minor oxide and trace element composition of 13 rock samples from hole no. 9-1, Watkins area, Adams County, Colo.

[Values are in either percent or parts per million. L after a value means less than the value shown, N means not detected, and B means not determined. S after the element title means that the values listed were determined by semiquantitative spectrographic analysis. The spectrographic results are to be identified with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, etc., but are reported arbitrarily as mid-points of those brackets, 1.0, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc. The precision of the spectrographic data is approximately one bracket at 68 percent, or two brackets at 95 percent confidence]

SAMPLE	Interval for analysis	SiO_2%	Al_2O_3%	CaO%	MgO%	Na_2O%	K_2O%	Fe_2O_3%	MnO%	TiO_2 %
D173453	0 - 15	59	14	2.1	1.12	0.55	2.4	6.0	0.11	0.63
D173454	18.1 - 21.6	68	15	.59	.96	.41	2.6	4.7	.043	.73
D173455	26.0 - 27.0	64	16	1.1	.99	.39	2.2	8.7	.13	.71
D173456	38.20 - 40.0	54	20	1.4	.68	1.44	4.1	7.6	.14	1.2
D173457	41.85 - 55.60	44	15	2.1	.88	.43	2.2	10	.21	.69
D173458	61.20 - 67.00	60	15	1.3	.87	.46	2.6	7.1	.10	.74
D173459	67.00 - 79.10	61	17	1.3	.99	.37	2.4	4.7	.10	.70
D173460	79.1 - 95.9	44	17	1.7	.96	.55	2.3	8.2	.27	.64
D173461	95.90 - 101.1	46	19	1.7	.84	.95	2.5	7.4	.21	.75
D173462	117.5 - 127.7	42	15	1.5	1.07	.52	2.1	10	.42	.64
D173463	127.7 - 140.1	46	14	5.0	.75	.91	2.8	5.3	.13	.62
D173464	140.1 - 146.9	47	17	1.4	1.00	.71	2.2	5.3	.067	.75
D173465	173.4 - 174.9	45	20	1.5	.96	.55	1.7	4.1	.020L	.74

SAMPLE	P_2O_5%	Cl%	As ppm	Cd ppm	Cu ppm	F ppm	Hg ppm	Li ppm	Pb ppm	Sb ppm	Se ppm
D173453	0.11	0.1L	5	1.L	33	630	0.05	25	25 L	0.8	0.4
D173454	.10L	.1L	5	1.L	60	655	.04	28	25 L	1.2	.6
D173455	.10L	.1L	5	1.L	47	495	.05	32	25 L	1.0	1.0
D173456	.14	.1L	3	1.L	47	650	.04	17	25 L	.6	.3
D173457	.27	.1L	4	1.L	38	930	.05	25	25 L	.7	2.1
D173458	.11	.1L	4	1.L	35	640	.03	22	25 L	.9	1.1
D173459	.10L	.1L	5	1.L	39	560	.05	30	25 L	1.0	.7
D173460	.13	.1L	4	1.L	57	650	.04	27	25 L	.9	.8
D173461	.10L	.1L	5	1.L	59	465	.09	23	25 L	.6	.7
D173462	.13	.1L	3	1.L	50	575	.05	22	25 L	.7	.3
D173463	.16	.1L	8	1.L	26	450	.02	10 L	25 L	.4	.1
D173464	.10L	.1L	3	1.L	44	555	.09	25	25 L	.6	.8
D173465	.10L	.1L	2	1.L	38	630	.24	20	25 L	.4	9.0

SAMPLE	Th ppm	U ppm	Zn ppm	B ppm-s	Ba ppm-s	Be ppm-s	Co ppm-s	Cr ppm-s	Ga ppm-s	La ppm-s
D173453	13	4.7	100	20	500	1.5	15	50	20	50
D173454	15	4.5	137	30	500	1.5	15	30	20	50
D173455	17	5.2	136	20	500	1.5	15	50	30	50
D173456	17	3.9	179	2 L	1000	2	10	20	30	70
D173457	14	5.5	103	2 L	300	1.5	7	30	30	50 L
D173458	12	4.2	128	2 L	300	1.5	7	30	20	50 L
D173459	15	4.6	114	20	300	1.5	10	70	20	50
D173460	20	5.0	110	2 L	300	3	7	30	30	70
D173461	19	4.9	130	2 L	500	2	7	10	30	70
D173462	14	4.4	123	2 L	300	1.5	7	30	20	50 L
D173463	8.1	2.3	110	2 L	500	N	10	15	20	50 L
D173464	16	4.7	142	2 L	500	1.5	10	30	20	70
D173465	18	3.5	147	2 L	300	N	7	15	30	70

Table 5.--Major and minor oxide and trace element composition of 13 rock samples from hole no. 9-1, Watkins area, Adams County, Colo.--Continued

SAMPLE	Mn ppm-s	Mo ppm-s	Nb ppm-s	Nd ppm-s	Ni ppm-s	Sc ppm-s	Sr ppm-s	V ppm-s	Y ppm-s	Yb ppm-s
D173453	300	5	15	70 L	15	10	300	100	30	3
D173454	200	10	15	70	15	10	200	100	15	1.5
D173455	500	10	15	N	20	10	300	150	15	3
D173456	500	3	15	70	10	30	500	200	30	3
D173457	500	N	15	N	10	10	200	100	20	2
D173458	300	3	15	N	15	10	150	100	15	2
D173459	300	3	15	70	15	15	200	150	15	2
D173460	1000	N	15	70 L	10	10	300	100	20	3
D173461	1000	N	15	70	50 L	15	300	100	20	3
D173462	1000	N	10	70 L	10	7	300	70	15	2
D173463	300	3	10 L	70 L	7	10	300	70	15	1.5
D173464	200	3	10	70	10	15	500	150	30	3
D173465	70	N	10	70	5	15	300	70	30	3

SAMPLE	Zr ppm-s	Total C%	Organic C%	Crbnt C%	Total S%
D173453	100	0.40	0.2	0.23	.24
D173454	100	.10	.1	.01L	.08L
D173455	100	.15	.1	.03	.14
D173456	100	.09	.1L	.03	.08L
D173457	70	.20	.1L	.12	.08L
D173458	70	.17	.1	.04	.08L
D173459	70	.59	.2	.35	.08L
D173460	70	1.50	.8	.70	.08L
D173461	100	.67	.2	.45	.08L
D173462	70	1.77	.5	1.24	.08L
D173463	70	1.39	.3	1.13	.08L
D173464	100	.66	.4	.31	.08L
D173465	150	.44	.4	.04	.08L

Table 6.--Average concentration of selected elements in sandstone, shale and the earth's crust.

[Expressed in percent and parts per million]

	Sandstone, average (Turekian and Wedepohl, 1961)	Shale, average (Turekian and Wedepohl, 1961)	Crustal, average (Taylor, 1964)
Si	36.8%	27.3%	28.15%
Al	2.5%	8.0%	8.23%
Ca	3.9%	2.21%	4.15%
Mg	0.7%	1.5%	2.33%
Na	0.33%	.96%	2.36%
K	10.7%	2.66%	2.09%
Fe	0.98%	4.72%	5.63%
Ti	0.15%	.46%	.57%
As	1. ppm	13 ppm	1.8 ppm
Cd	0.0X[1]	.3 ppm	.2 ppm
Cu	X	45 ppm	55 ppm
F	270 ppm	740 ppm	625 ppm
Hg	.03 ppm	.4 ppm	.08 ppm
Li	15 ppm	66 ppm	20 ppm
Pb	7 ppm	20 ppm	12.5 ppm
Sb	0.0X	1.5 ppm	.2 ppm
Se	.05 ppm	.6 ppm	.05 ppm
Th	1.7 ppm	12 ppm	9.6 ppm
U	0.45 ppm	3.7 ppm	2.7 ppm
Zn	16 ppm	95 ppm	70 ppm
B	35 ppm	100 ppm	10 ppm
Ba	XO. ppm	580 ppm	425 ppm
Be	0.X	3 ppm	2.8 ppm
Co	0.3 ppm	19 ppm	25 ppm
Cr	35 ppm	90 ppm	100 ppm
Ga	12.0 ppm	19 ppm	15 ppm
Mo	0.2 ppm	2.6 ppm	1.5 ppm
Ni	2 ppm	68 ppm	75 ppm
Sc	1 ppm	13 ppm	22 ppm
Sr	20 ppm	300 ppm	375 ppm
V	20 ppm	130 ppm	135 ppm
Y	40 ppm	26 ppm	33 ppm
Yb	4 ppm	2.6 ppm	3.0 ppm
Zr	220 ppm	160 ppm	165 ppm

[1]X indicates that only order of magnitude estimates could be made.

Table 7.--Physical property tests of selected overburden core samples - Hole 9-1.

Sample	Depth (feet)	Pulse Velocity (feet/sec.)	Shear Velocity (feet/sec.)	Density (lb/ft^3)	Static Young's Modulus @ 2000 lb. load (psi)	Static Poisson's Ratio	Uniaxial Compressive Strength (psi)
Denver Lignite							
R13, Hole 9-1	128.0-128.5	4289	2285	128	$.47 \times 10^5$ $.067 \times 10^5$	..068 .008	947 ---
R16	147-159	5327	3219	128	$.80 \times 10^5$ 1/	.096	1531
R15	160-165	3858	----	---	----	---	---

Physical property tests by James R. Aggson, U.S. Bureau of Mines, Denver Mining Research Center.

1/ @4000 lb. load.

To convert:

Feet (ft) to meters (m) multiply by .3048.

Pounds per cubic foot (lb/ft^3) to gram per cubic centimeter (g/cm^3) multiply by .016

Pounds per square inch (lb/in^2) to gram per square centimeter (g/cm^2) multiply by 70.4

Meters per second (m/s) to feet per second (ft/s) multiply by .3048

Location 50m east of N-S line, 602m south of E-W line Near Watkins, Colorado **Hole No.:** 3-1

SW NW NW **Sec.** 17 **Tp.** 3 S. **Rg.** 65 W. **Project:** Denver Basin Lignites

Elevation: 5447 ft. 1660.25m **Datum:** Surface **Type Log:** Cutting to 15' thence core to 60'

Drilled by: Colorado School of Mines **Dates:** **Spud:** 9-3-75

Address: Golden, Colorado **Completion:** 9-4-75

Driller(s): Charles Powell **Geologist:** J. D. Sanchez

Drill & Type: Mayhew 1000, Rotary **Total Depth:** 60'

Hole Angle at Surface & Deviations: Vertical

Bit Size, Type & Intervals Used: 5 5/8" rock bit to 15' thence 4.5' tungsten carbide bit for coring to 47' thence rock bit remainder.

Core Barrels: 2 1/4"

Cored Intervals:

Casing: 15' P.V.C. at top, I.D. 3" **Perforations:** ---

Air &/or Fluid: Water with Baroid Quik-Gel, air at 32' and down

Other Logs & Remarks: Natural Gamma (Bill Larson--U.S. Bureau of Mines)

LOG				CORE			
From	To	Length	Description	No.	From / To	Foot Rec'd	% Rec'd
0'	15'	15'	Mudstone, dark gray, silty (hard) with carbonaceous streak near bottom			rock bit to 15'	
15'	28'	13'	Lignite zone (core)	1	15' / 28'	0	0%
28'	34'	6'	Lignite zone	2	28' / 34'	0	0%
34'	44'	10'	Mudstone and fine-grained sandstone	3	34' / 47'	3'	23%
44'	44.6'	.6'	.2' siltstone; .4' lignite				
44.6'	47'	2.4'	Mudstone, medium gray with limonite stains, .1' lignite at bottom				
			End of core-rock bit to 60'				
47'	60'	13'	Mudstone, alternating browns to medium gray, (plastic) or displays plasticity (rock bit)				

1500m east of N-S line, 2.5m south of E-W line

Location Near Watkins, Colorado **Hole No.:** 7-11

NW, NE, SE **Sec.** 17 **Tp.** 3 S. **Rg.** 65W **Project:** Denver Basin Lignites

Elevation: 5460 ft. / 1664 m. **Datum:** Surface **Type Log:** Cuttings 0'-45', Core description 45'-87'

Drilled by: Colorado School of Mines **Dates:** **Spud:** 9-4-75

Address: Golden, Colorado **Completion:** 9-4-75

Driller(s): Charles Powell **Geologist:** J. D. Sanchez

Drill & Type: Mayhew 1000, Rotary **Total Depth:** 87'

Hole Angle at Surface & Deviations: Vertical

Bit Size, Type & Intervals Used: 5 5/8" rock bit for 45' thence 4.5" tungsten carbide bit for coring remainder of depth

Core Barrels: 2½"

Cored Intervals: 45' to 87'

Casing: None **Perforations:** --------

Air &/or Fluid: Water with Baroid Quik-Gel

Other Logs & Remarks: Rock bit to 45' thence core clay bit, Natural Gamma (Bill Larson - U.S. Bureau of Mines)

LOG				CORE			
From	To	Length	Description	No.	From / To	Foot Rec'd	% Rec'd
0'	15'	15'	Sandstone, silty to clayey, with rounded particles of quartz, light brown	1	0 / 15'	rock bit	
15'	30'	15'	Sandstone, silty to clayey, with rounded particles of quartz, light-brown	2	15 / 30'	rock bit	
30'	38'	8'	Sandstone, silty; reddish brown with iron stains	3	30' / 45'	rock bit	
38'	45'	7'	Mudstone, gray to very dark gray, very clayey to silty (with kaolinite particles?)			rock bit	
45'	47'	2'	Lignite zone	4	45' / 47'	0	
47'	52'	5'	Lignite zone with partings, (predominantly partings); parting at about 48' (1'thk), 50' (1'thk), 51' (1' thk),	5	47' / 57'	5'	50%
52'	57'	5'	Lignite zone (core loss 5')			0	0%
57'	67'	10'	Lignite and partings; parting (61.8'- 62.3')	6	57' / 67'	10'	100%
67'	77'	10'	Lignite and partings; mudstone (76.0' -77.0')	7	67' / 77'	10'	100%
77'	87'	10'	Mudstone, medium gray, with shaley mudstone at 73' (approx. 3'), with partings.* *Note full core barrel but core was stuck in it, lost a lot of core while trying to take it out of the core barrel! (14)	8	77' / 87	10'	100%

Location 50m east of N-S line; 1102m south of E-W line **Hole No.:** 9-1

SW NW SW **Sec.** 17 **Tp.** 3 S. **Rg.** 65 W. **Project:** Denver Basin Lignite

Elevation: 5540 ft 1688.5m **Datum:** Surface **Type Log:** cutting, 0'-15' core 15--186'

Drilled by: Colorado School of Mines **Dates:** **Spud:** 5/2/75

Address: Golden, Colorado **Completion:** 5/5/75

Driller(s): Charles Powell **Geologist:** Norton, Malotte, Sanchez

Drill & Type: Mayhew 1000 rotary **Total Depth:** 186'

Hole Angle at Surface & Deviations: vertical

Bit Size, Type & Intervals Used: 4 3/4 T.C. Tooth

Core Barrels: 4 1/2" X 2 1/4" DB swivel type

Cored Intervals: 15'-186';

Casing: 140' of 3" I.D. PVC **Perforations:** ---

Air &/or Fluid: Air, 0'-35'; water, with Baroid Quik-Gel 35'-186'

Other Logs & Remarks: Resistivity: single point 8" normal and 16" normal; Natural Gamma Gamma-Gamma density; Neutron; Caliper; Spontaneous Potential (Bill Larson--U.S. Bureau of Mines)

LOG				CORE			
From	To	Length	Description	No.	From To	Foot Rec'd	% Rec'd
0'	3'	3'	Soil, light brown to brown, aeolian?				
3'	15'	12'	Sandstone; mudstone; gray, heavy limonitic				
			stain and weathered, crystals of gypsum ±				
			5mm at ± 9'				
			Add core barrel/drilling with air				
15.0'	15.9'	0.9'	Mudstone; brown, lignitic streaks	1	15/25	6.2'	62%
	18.1'	2.2'	Lost				
	21.6'	3.5'	Sandstone; tan, fine-grained with limonitic				
			stain				
	22.0'	0.4'	Mudstone; gray, carbonaceous material				
			at top 0.1'				
	23.0'	1.0'	Sandstone; tan, course-grained, gypsiferous				
	23.5'	0.5'	Mudstone; gray, carbonaceous and gypsiferous				
	25.0'	1.5'	Lost				
25.0'	26.0'	1.0'	Lost	2	25/35	1.0'	10%
	27.0'	1.0'	Mudstone; gray, limonitic and gypsiferous				
	35.0'	8.0'	Lost				
			Convert from air to mud				

Log Continuation: Hole No: 9-1

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LOG				CORE			
From	To	Length	Description	No.	From To	Foot Rec'd	% Rec'd
35.'	35.7'	0.7'	Mudstone; gray, limonite stains	3	35/45	7.9'	79%
	36.4'	0.7'	Lost				
	37.9'	1.5'	Mudstone; gray				
	38.2'	0.3'	Mudstone; gray, interspersed sand grains				
	40.0'	1.8'	Sandstone; coarse-grained, limonite stains,				
			0.15' carbonaceous zone at 39.2', limonite				
			stains below				
	41.85'	1.85'	Mudstone; carbonaceous (plant fragments)				
	43.15'	1.3'	Mudstone; gray with interbedded sandstone,				
-	-		limonite stain (lost .30')	-			
	43.9'	0.75'	Mudstone; gray, fractured				
	45.0'	1.1'	Lost				
45.0'	55.0'	10.0'	Lost	4	48/55	0'	0%
55.0'	55.6'	0.6'	Sandstone; tan with interbedded mudstone	5	55/64	3.6'	40%
	55.8'	0.2'	Mudstone; gray, (75° slickenside)				
	61.2'	5.4'	Lost				
61.2'	64.0'	2.8'	Sandstone; tan, fine-to medium-grained,				
			friable, sealed fractures				
	65.6'	1.6'	Sandstone; very fine-grained, interbedded				
			mudstone, grades to sandstone, very fine-				
			grained, fractures in upper .2'	6	64/74	9.'	90%
	66.3'	0.7'	Mudstone, with some fine-grained sandstone	-	-		
	66.8'	0.5'	Lost				
	67.0'	0.2'	Sandstone; with interbedded gypsum				
	70.8'	3.8'	Mudstone; with interbedded fine grained				
			sandstone, limonitic streak; grades to				
			less sandstone near bottom				
	71.3'	0.5'	Lost				
	71.8'	0.5'	Lignite; with interbedded shale at top				
			and bottom				

Log Continuation: Hole No: 9-1

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LOG				CORE			
From	To	Length	Description	No.	From To	Foot Rec'd	% Rec'd
	74.0'	2.2'	Mudstone; with some interbedded sandstone				
			increasing to bottom				
74.0'	78.3'	4.3'	Mudstone; gray, carbonaceous plant material				
			scattered throughout	7	74/84	10.0'	100%
	78.8'	0.5'	Siltstone; tan, cross-bedded, limonitic				
			stains				
	79.1'	0.3'	Sandstone; gray, friable and poorly				
			cemented				
	81.2'	2.1'	Mudstone; gray, carbonaceous stringers of				
			lignite and plant material				
	81.8'	0.6'	Mudstone; lignite stringers				
	83.1'	1.3'	Mudstone; gray, 60° fracture at 80.2'				
	83.5'	0.4'	Siltstone; gray				
	84.0'	0.5'	Mudstone; gray				
84.0'	87.8	3.8'	Mudstone; gray, occasional carbonaceous				
			plant material, slickenside at 89.3' -- 20°	8	84/94	9.2'	92%
	89.8'	2.0'	Siltstone; gray, abundant slickensides				
			(apparent movement) 40°				
	92.1'	2.3'	Mudstone; with interspersed sandstone,				
			some carbonaceous plant material in less				
			sandy zones, bottom 0.3' badly broken,				
			slickensides				
	92.9'	0.8'	Loss (broken zone)				
	93.7'	0.8'	Mudstone; gray				
	94.0'	0.3'	Mudstone; gray, broken				
94.0'	94.3'	0.3'	Mudstone; gray, occasionally plant				
			material	9	94/104	7.1'	71%
	95.3'	1.0'	As above, more plant material				
	95.9'	0.6'	Mudstone; gray, carbonaceous, 2 stringers				
			of lignitic material, slickensides				

Log Continuation: Hole No: 9-1

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LOG				CORE			
From	To	Length	Description	No.	From / To	Foot Rec'd	% Rec'd
	101.1'	5.2'	Mudstone; gray, with green caste				
			less plant material,				
			broken				
	104.0'	2.9'	Lost				
104.0'	114.0	10.'	Lost (core catcher failure)	10	104/114	0'	0%
104.0'	117.3	3.3'	Lost	11	114/124	6.7'	67%
	118.4'	1.1'	Mudstone; gray, occasional plant material,				
			45° fracture at 117.8' and 118.0'				
	119.0'	0.6'	As above with occasional sandstone				
	120.4'	1.4'	Mudstone; gray				
	120.7'	0.3'	Mudstone; sandy, buff-gray				
	122.2'	1.5'	Mudstone; gray with occasional plant				
			material				
	122.5'	0.3'	Mudstone; sandy				
	123.5'	1.0'	Mudstone; gray				
	124.0'	0.5'	Mudstone; gray, sandy, occasional vugs				
			or worm tubes				
124.0'	127.7'	3.7'	Siltstone; gray, irregular bedding,				
			carbonaceous plant material, numerous				
			buff borings or worm tubes.	12	124/135	11.'	100%
	135.0'	7.3'	Sandstone; medium to dark gray, coarse				
			grained, micaceous, plant material				
			throughout; carbonaceous zone at 129.0',				
			129.5', 133.7' and base				
135.0'	140.1'	5.1'	As above, with some buff stringers of				
			siltstone	13	135/144	9.0'	100%
	144.0'	3.9'	Mudstone; gray, carbonaceous plant				
			material, some buff to brown borings or				
			worm tubes				

Log Continuation: Hole No: 9-1

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LOG				CORE			
From	To	Length	Description	No.	From / To	Foot Rec'd	% Rec'd
144.0'	146.87	2.87'	Mudstone; gray with stringers of lignitic material	14	144/155	11.0'	100%
			Lignite zone 146.87' - 178.00'				
	147.06	0.19'	Lignite; fair				
	147.71	0.65'	Sandstone; with interbedded lignite				
	147.97	0.26'	Lignite; fair				
	148.23	0.26'	Lignite; sandy to sandstone, lignitic				
	148.34	0.11'	Sandstone; carbonaceous				
	148.66	0.32'	Lignite; good				
	149.18	0.52'	Sandstone; lignitic				
	149.24	0.06'	Lignite; sandy				
	149.27	0.03'	Sandstone; lignitic				
	149.36	0.09'	Lignite				
	149.42	0.06'	Sandstone; lignitic				
	149.73	0.34'	Lignite; good				
	149.90	0.17'	Lignite; poor				
	149.98	0.08'	Sandstone; lignitic				
	149.99	0.01'	Lignite				
	150.03	0.04'	Sandstone; lignitic				
	150.09	0.06'	Lignite				
	150.27	0.18'	Sandstone; lignitic				
	150.47	0.20'	Lignite; sandy				
	150.82	0.35'	Sandstone; lignitic				
	150.88	0.06'	Lignite				
	150.95	0.07'	Sandy; lignite				
	152.60	1.65'	Lignite; broken (cleats and butt faces)				
	152.67	0.07'	Sandstone; lignitic				
	152.91	0.24'	Lignite				
	152.98	0.07'	Sandstone; slightly lignitic				
	153.15	0.17'	Lignite				

Log Continuation: Hole No: 9-1

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LOG				CORE			
From	To	Length	Description	No.	From / To	Foot Rec'd	% Rec
	153.29	0.14'	Sandstone; very lignitic				
	153.42	0.13'	Lignite				
	153.74	0.32'	Sandstone; silty, carbonaceous				
	154.32	0.58'	Lignite				
	154.51	0.19'	Sandstone; lignitic				
	154.86	0.35'	Lignite				
154.86	154.90	0.04'	Lignite	15	154.86 /165	10.14'	100%
	154.97	0.07'	Sandstone; lignitic				
	155.04	0.07'	Lignite				
	155.06	0.02'	Sandstone; Lignitic				
	155.08	0.02'	Lignite				
	155.36	0.28'	Sandstone; lignitic				
	155.42	0.06'	Lignite				
	155.85	0.43'	Sandstone; lignitic				
	156.16	0.31'	Lignite				
	156.19	0.03'	Sandstone; lignitic				
	157.12	0.93'	Lignite				
	157.65	0.53'	Sandstone; lignitic				
	158.96	1.31'	Lignite				
	159.06	0.10'	Sandstone; lignitic				
	159.21	0.15'	Lignite				
	159.46	0.25'	Sandstone; lignitic				
	165.32	5.86'	Lignite; broken (cleat and butt faces) no				
			significant partings				
165.32	170.82	5.50'	Lignite; poor recovery, partings of .08,				
			.04, .04, 1.0± lignite recovered	16	165/ 175	4.0'	40%
	172.02	1.20'	Sandstone; silty with lignitic streaks at				
			172.07'-.1'; 172.52'-.05'; 172.97-.1';				
			0.1' loss at 172.32'				
	173.42	1.4'	Lignite; small losses total 0.4'				

Log Continuation: Hole No: 9-1

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LOG				CORE			
From	To	Length	Description	No.	From To	Foot Rec'd	% Rec'd
	174.87	1.45'	Mudstone; gray.with greenish tint or caste				
			; plant material present				
	175.03	0.16'	As above, dark gray to black; sharp				
			contact fracture; vertical feather and				
			flute type fractures 0.5' length at				
			bottom of core.				
175.03	176.00	.97+'	Lost (lignite?)	17	175/186	5.3'	48%
	176.10	0.1'	Sandstone; lignitic				
	176.15	.05'	Lignite				
	176.20	.05'	Sandstone, lignitic				
	176.30	0.10'	Lignite; bone				
	176.50	0.20'	Sandstone; lignitic				
	177.20	0.70'	Lignite; probable small loss				
	177.70	0.50'	Mudstone; dark gray				
	177.85	0.15'	Lignite; bone				
	177.90	0.05'	Sandstone; lignitic				
	178.15	0.25'	Lignite; bone				
	178.35	0.20'	Sandstone; lignitic				
	178.55	0.20'	Lost (lignite?)				
	180.65	2.10'	Mudstone; gray, plant material				
	181.10	0.45'	Lignite; minor bone				
	181.50	0.40'	Mudstone; gray, plant material				
181.50	186.00	4.50'	Lost				
			Total depth 186'				
			5/5/75				

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REFERENCES

Bohor, B. F., Hatch, J. R., and Hill, D. J., 1976, Altered volcanic ash partings as stratigraphic marker beds in coals of the Rocky Mountain region, AAPG Bull. vol. 60, no. 4, p. 651

Landis, E. R., 1959, Coal resources of Colorado: U.S. Geol. Survey Bull. 1072-C, plate 2.

Sanchez, J. D., 1976, Correlation of shallow lignite beds in the Denver Formation near Watkins, Colorado, using lithologic and gamma ray logs, U.S. Geol. Survey Open-File Report 76-279.

Soister, P. E., 1974, A preliminary report on a zone containing thick lignite beds Denver basin, Colorado: U.S. Geol. Survey Open-File Report 74-27, 64 p., 7 figs., 4 tables.

Taylor, S. R., 1964, Abundance of elements in the continental crust-- a new table: Geochim. et Cosmoshim, Acta. v. 28, p. 1273-1285.

Turekian, K. K., and Wedepohl, K. H., 1961, Distribution of the elements in some major units of the Earth's crust: Geol. Soc. America Bull., v. 72, p. 175-192