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GEOLOGICAL SURVEY

A PRELIMINARY REPORT ON A ZONE CONTAINING THICK LIGNITE BEDS DENVER BASIN, COLORADO

By Paul E. Soister

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CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

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ABSTRACT

A zone of lignite beds of Paleocene age in the Denver Formation (Upper Cretaceous and Paleocene) lies about 800-1,500 feet above the well-known and extensively mined coal beds of the Laramie Formation (Upper Cretaceous). The zone is a few hundred to as much as 500 feet thick. Where lignite beds lie within 1,000 feet of the surface, this zone underlies an area about 30 miles wide by about 75 miles long, stretching from just northeast of Denver to several miles south of Calhan. Fifteen mines were operated at various periods between 1874 and 1940 and probably produced a total of less than 100,000 tons of lignite, mostly for local use.

From 1874 to 1974, several geologists have reported on this lignite zone or the enclosing beds, but no detailed reports have been written except for one by this writer. Drill holes are the main source of geologic data, owing to poor exposure.

There are generally about 3 to 6 lignite beds, and they are mostly about 15 or 20 to a few tens of feet apart. Most or all beds typically contain numerous non-coal partings from a fraction of an inch to several inches thick, so that thickness of lignite beds should be stated as gross thickness and as net lignite thickness; net lignite thickness is generally from 70 to 90 percent of gross thickness. Many partings are composed of kaolin, but others are composed of other clay minerals, siltstone, and sandstone. The lignite beds range generally from 1 or 2 to several feet thick, and some are as much as 10-25 feet thick; the thickest known bed has a maximum thickness of 54.5 feet, with a net lignite thickness of 40 feet. Most lignite beds seem to have fair lateral continuity, and at least some beds are several miles in extent. The thickest known lignite bed was traced for at least 18 miles, from northwest to southeast of Watkins.

The lignite is brownish-black to black, weathers, checks, and disintegrates rapidly, and even in drill cores from a few hundred feet in depth the lignite is easily broken by hand pressure. Quality of the lignite is lowered by the non-coal partings and, locally at least, by some small blebs and balls of clay in the lignite itself, especially at

the base. Available analyses indicate that the following general figures, on an as-received basis, may be applied to relatively clean lignite from this zone: 6,000-7,000 Btu, 20-35 percent moisture, 8-18 percent ash, and 0.3-0.5 percent sulfur. Rank of the lignite is lignite A as calculated by the formulas of the American Society for Testing and Materials (ASTM), although some parts, especially of deeper beds, may be as high as subbituminous C coal in rank.

Best utilization of the lignite probably would be by gasification, liquefaction, or similar methods, because of the numerous non-coal partings and low quality.

The thickest known lignite bed is estimated to contain at least 1.25 billion short tons of lignite. Two methods of roughly estimating the order of magnitude of lignite resources, in beds at least 4 feet thick and within 1,000 feet of the surface in this zone, indicate resources are on the order of 20 billion tons.

INTRODUCTION

There are two main coal zones in the Denver Basin, Colorado--a lower zone of Late Cretaceous age and an upper zone of Paleocene age. As used in this report, the Denver Basin refers to the area between the South Platte River, the Arkansas River, the Front Range of the Rocky Mountains, and about the eastern limit of the lower coal zone.

The lower of these zones contains subbituminous coal and is in the Laramie Formation of Late Cretaceous age. Virtually all coal produced in the Denver Basin--more than 100 million tons (Lowrie, 1966, p. 9)--has been from this zone. Production from the Laramie began in the 1800's and still continues in a few mines of the Boulder-Weld field.

The upper of the two coal zones contains lignite and is in the Denver Formation of Late Cretaceous and Paleocene age. This lignite zone, the subject of this report, has been dated by fossil evidence as Paleocene. Very minor production from this lignite zone occurred intermittently, mostly from about the 1860's to the 1940's. Total known production is 42,633 short tons, but records are incomplete. Total production was probably less than 0.1 percent of total Denver Basin production.

The lignite beds lie in an area about 75 miles long from north-northwest to south-southeast and about 30 miles wide, where they crop out or are within 1,000 feet of the surface. They generally range from about 800 feet above the Laramie coal beds on the east to about 1,500 feet above on the west. In the Strasburg NW quadrangle a few miles southeast of Watkins, the lignite zone is about 500 feet thick and the interval from the base of the Laramie coal zone to the top of the lignite zone is 1,600 feet (Soister, 1972).

LARAMIE COAL ZONE

Although the subbituminous coal zone of the Laramie Formation is not the main topic of this report, a brief description is given here to place the lignite zone in the proper perspective.

The heavy line labeled "Edge of Laramie Coal Zone" on figure 1 marks the approximate eroded edge and represents the stratigraphically lowest extensive coal bed. The edge is obscured by thick Quaternary deposits on the northeast and southeast sides of the basin. Along the edge in other areas the basal coal beds are exposed at intermittent intervals. The edge shown on the map in the northeast is modified from an unpublished map of the Colorado State Planning Commission (1940a) after examining a report by Bjorklund and Brown (1957) and more recent well logs. The eastern edge is essentially after Dane and Pierce (1936). The southeast covered edge is approximate and has been determined by examining water-well logs and copying two small outcrop lines from a map by R. C. Coffin (1921). The southwest edge is based on my detailed mapping (Soister, 1968a and 1968b) and on an unpublished map (Colorado State Planning Commission, 1940b). On the west side of the basin, the coal beds are interrupted by faults along which younger rocks are placed against rocks much older than the Laramie (Burbank and others, 1935; Scott, 1962, 1963; and Smith, 1964). Only those faults that are important to the edge of the coal beds are shown on figure 1; numerous faults cutting the Laramie coal beds in the Boulder-Weld coal field are omitted. The edge of the Laramie coal zone shown in the northwest part of the Denver Basin is based on study of water well and coal exploration drill-hole logs and on various reports (Colo. State Planning Commission, 1940a; Soister, 1965; Spencer, 1961).

The coal beds dip downward from the periphery toward the axis of the Denver Basin. This axis lies along a line from near the Black Forest area to Denver and then northeastward under the Fort Lupton area. The base of the main Laramie coal zone coincides with the top of the most extensive sandstone aquifer of the Denver Basin. Elevations of and depths to this aquifer (and the base of the Laramie coal zone) are shown by Romero and Hampton (1972).

Numerous mines have worked these coal beds around the periphery of the Denver Basin, mostly in the Boulder-Weld and Colorado Springs fields (Goldman, 1910; Landis, 1959; Lowrie, 1966; Soister, 1968a, 1968b; Spencer, 1961). No mining has been undertaken where these beds are more than about 500-1,000 feet deep, and characteristics of the coal beds over most of the basin are virtually unknown.

THE LIGNITE ZONE

History of Geologic Work

Except for the present author's work, no detailed report has been written on this lignite zone. The only detailed report on the zone is

a U.S. Geological Survey open-file report on one 7½-minute quadrangle, the Strasburg NW (Soister, 1972); similar reports on the Strasburg SW, Watkins, and Watkins SE quadrangles are being completed. Additional study is underway on the rest of the area underlain by the lignite zone.

Previous geologic work on the lignite zone is summarized in this report in chronological order. However, measured coal sections and mine descriptions are given later in this report.

Arch R. Marvine (1874, p. 120, 121) in writing of coal mines east of Denver, says of a coal outcrop on the east bank of Coal Creek (sec. 20, T. 4 S., R. 65 W.) that "It was near here that the first discoveries of coal were made in Colorado * * *."

George H. Eldridge (Emmons, Cross, and Eldridge, 1896, p. 373-386) briefly described lignite beds of this zone because of mining then under way in the Scranton mine area northwest of Watkins. Eldridge (p. 375) said "The coal is a thoroughly representative type of the lignite of the plains; its streak is brown, it weathers rapidly and disintegrates completely; it contains 25 percent water, yields a large amount of ash, and burns with evolution of comparatively little heat." He gave analytic data about a bed worked at the Scranton mine. Eldridge considered the lignite to be in the "upper shaly division of the Laramie." However, more recent work shows it to be in beds equivalent to the type Denver Formation, and the present author places the lignite in the Denver.

G. B. Richardson (1917), in a reconnaissance study in 1910-11, traced this lignite zone "over a considerable area on the plains" and correlated these beds in the Calhan and Fondis areas with beds in the Scranton mine area. However, he published no map or other illustrations of this work. Richardson also stated that the lignite beds are of post-Laramie age. His conclusion was based on findings of F. H. Knowlton that leaves collected by Richardson and C. W. Cooke were "of post-Laramie (Denver) age." Richardson concluded that this indicated a "modification and delimitation of the Laramie Formation in the type area."

Carle H. Dane and William G. Pierce (1936) did reconnaissance mapping in the southeastern part of the Denver Basin in 1931-1932. The results of their mapping were used in the most recent U.S. Geological Survey geologic map of Colorado (Burbank and others, 1935). A small-scale reconnaissance geologic map by Dane and Pierce (1936, fig. 3) shows coal beds cropping out near Ramah and Calhan, and four small mines of the lignite zone, as well as mines in the Laramie. They discussed the general lithology of the lignite zone, which is in what they termed the "lower division" of the Dawson Arkose; they gave some measured surface and mine sections of lignite beds, and some coal analyses, and discussed the age and relations of the lignite-bearing beds with the Laramie Formation.

Roland Brown (1943) made field studies in the Denver Basin in 1939-1941 to ascertain the Cretaceous-Tertiary boundary. Brown (p. 76) stated that plant fossils found in the lignite zone in the vicinity of Ramah are "typical Paleocene flora similar to that in and above the mammal beds on South Table Mountain at Golden." The latter beds are in the Denver Formation; thus, placing the lignite zone in the Denver is proper insofar as age is concerned. Brown (p. 72) also traced the lignite zone from the vicinity of Ramah "to a point 10 miles north of Fondis." Mammal fossils of Paleocene age found on Corral Bluffs (Brown, 1943, p. 75), one of which is in a slightly different location than cited by Brown (Soister, 1968a), are either below or in the lower part of the lignite zone. Thus, the Cretaceous-Tertiary boundary is at least a few hundred feet below the main lignite beds of this zone.

Thad G. McLaughlin (1946) in 1940 studied the strata of southeastern Denver Basin in connection with ground-water work. He mentioned the lignite beds in this study and showed thicknesses of coal beds in several water-well logs. McLaughlin also used Dane and Pierce's "lower division of Dawson arkose" for the beds containing the lignite.

Stanley O. Reichert (1954) does not discuss the lignite zone except to state that the Denver Formation (of the Golden area) is, in his opinion, "the time equivalent of the upper part of the lower Dawson as mapped by Dane and Pierce, 1936 * * *."

Alex D. Elkin (1958, p. 6) said that "Most of the deposits formerly included in the 'lower Dawson formation' (Dane and Pierce, 1936, and McLaughlin, 1946) are in this report assigned to the Denver formation." Elkin mentioned (p. 7) that "Several thin coal beds are present in the upper part of the formation."

Edwin R. Landis (1959) has written the latest U.S. Geological Survey report on coal resources of Colorado, including the Denver Basin. His calculations of the reserves of the lignite zone were included under subbituminous coal, although he wrote (p. 163) that "there is a strong possibility that it is actually lignite." Landis' calculations were based on only the few small mines and on a few drill holes and outcrop descriptions and include only a small part of the total area underlain by the lignite zone. Landis summarized mining activity and analyses in part of the lignite zone.

The present author prepared a detailed map of the Strasburg NW quadrangle and graphic sections of 22 coal prospecting and 10 water-well logs (Soister, 1972). This is the only detailed publicly available report showing a part of the lignite zone.

History of Mining Activity

General Statement

Only 15 mines in the lignite zone are recorded, all in published and unpublished governmental reports. Most mines were quite small.

The earliest production may have been in the 1860's but the earliest recorded was in 1886. Several small mines for local use were active in the 1920's and 1930's. Most of the mines were for local use only and had very minor production. Latest recorded production was in 1940. Total production of 42,633 tons from only six of the mines can be accounted for in the incomplete records available (table 1). Total production of all mines was apparently less than 100,000 tons and thus less than one-tenth of one percent of total Denver Basin production.

Discussion of each mine will be in chronological order, from approximately the oldest to the youngest, insofar as feasible. Mines for which no data on ownership are available are simply designated unnamed mines.

Table 1.--Coal production from known mines

Mine and/or location	Date of operation	Production (short tons)
1. Sec. 20, T. 4 S., R. 65 W.	Before 1874	Unknown
2. Scranton (3 mines), secs. 16, 28, 29, T. 3 S., R. 65 W.	Before 1874 to 1900	35,789+
3. M. M. & P.	Before 1909	70+
4. Mosby's	1909-1911 or later	600+
5. Sec. 30, T. 11 S., R. 60 W.	Before 1910	Unknown
6. Purdon	Before(?) 1909 to after 1910	Unknown
7. Sec. 34, T. 6 S., R. 62 W.	Before 1910(?)	Unknown
8. Sec. 35, T. 5 S., R. 62 W.	Before 1910(?)	Unknown
9. Fondis	1913(?) to 1937	4,409+
10. Valley	Before(?) 1936 to after 1937(?)	225+
11. Stander	1934-1940	1,540
12. Bates	Before and after 1935	Unknown
13. Sec. 6, T. 5 S., R. 63 W.	1934	None(?)
	Total known production-----	42,633

Mines and Production

Unnamed mine: NE¼NE¼ sec. 20, T. 4 S., R. 65 W., Arapahoe County.--Marvine (1874, p. 120-121) gave an inexact location (T. 4 S., "and probably between ranges 65 and 66 west") for a coal mine shaft near the

site of "the first discoveries of coal" in Colorado (on the east bank of Coal Creek). Eldridge (Emmons, Cross, and Eldridge, 1896, p. 317) cited this location as "at a prominent lignite outcrop still visible in the north bank of the Creek * * *." An unpublished U.S. Geological Survey map of 1910 by E. G. Woodruff, assisted by D. E. Winchester, shows a coal mine located in the center, NE¼NE¼ sec. 20 (corrected by inspection of modern topographic map by present author). The old map has a notation indicating a 6-foot coal bed. This old mine probably supplied part of the coal used in the young city of Denver and surrounding communities, but no production figures are available.

Scranton mine(s): Secs. 16, 28, and 29, T. 3 S., R. 65 W., Adams County.--Marvine (1874, pl. IV) showed two coal mine shafts in sec. 28 but nothing in sec. 16. However, in the text (p. 121) he queried sec. 28 in stating that there "are two shafts which reach coal, and on which work has been done now and then for some years." He cites one of these shafts as being the probable location of a stratigraphic section measured by E. B. Malley; this section shows an 8-foot coal bed with a 4-inch black clay parting, the top of the coal being 39½ feet below ground surface.

George H. Eldridge (Emmons, Cross, and Eldridge, 1896, p. 320) in a table of Denver Basin mines, listed "Two shafts, T. 3 S., R. 65 W., sec. 28. Tonsland. Abandoned prior to 1872." Tonsland is shown at the location of the present town of Watkins. The unpublished 1910 map by Woodruff and Winchester shows a mine symbol labeled "Shaft 8' coal at 80'" in center S½S½NW¼SE¼ sec. 28; also, in the center of sec. 29 another symbol is labeled "Shaft 6' at 90'." Inasmuch as this map should be much more accurate than the earlier maps mentioned above, these two shafts may represent the two labeled "sec. 28" in the older maps and reports. Otherwise, the sec. 29 mine dates from about 1896 or later and one of the sec. 28 mines is not represented on Woodruff and Winchester's map.

Woodruff and Winchester's map (unpublished, 1910) has a mine symbol labeled "Scranton coal mine" just north of the south line, SW cor. SE¼ sec. 16. The sec. 16 "Scranton coal mine" apparently postdates the sec. 28 mine(s) because Marvine (1874) did not show the former. Eldridge (Emmons, Cross, and Eldridge, 1896, p. 320) listed the Scranton mine, with a location of Scranton (town no longer in existence) and stated that it "Produced prior to 1889. Since abandoned." However, on page 373 of the same reference, Eldridge wrote that "A seam is opened at Scranton which has a thickness of over 10 feet, including partings * *." It is unclear whether Eldridge implied that mining was going on at the time of his work. No mention was made by Eldridge as to quantity of coal produced in any of the mines.

Although, as stated above, Eldridge showed two shafts in sec. 28 "abandoned prior to 1872," the Colorado State Coal Mine Inspector's Office files show production during 1886 to 1900 from sec. 28. This

time period coincides with Eldridge's field and office work on this area. It is therefore uncertain precisely which mine or mines should be credited with this production.

The State Coal Mine Inspector's Office files show the following:

Town or post office: Scranton. Sec. 28, T. 3 S., R. 65 W.

Subbituminous coal
Operators: 1886, R. M. McDowell; Denver R. R. Land & Coal Co.
1890, Denver R. R. Land & Coal Co.
1891, Colorado Eastern R. R. Coal Co. (Boston Bldg., Denver). Latest operator.

Production:	Year	Tons	
	1886	11,000	
	1887	16,000	Thickness of seam, 7 feet
	1888	1,700	
	1889	900	
	1890	681	
	1891	1,273	
	1892	654	
	1893	633	
	1894	604	
	1895	540	
	1896	398	
	1897	413	
	1898	514	
	1899	439	
	1900	40	
Total production-------		35,789	

M. M. and P. mine: NE¼NE¼NW¼ sec. 19, T. 13 S., R. 61 W., El Paso County.--There is some uncertainty as to whether more than one mine had been worked in sec. 19. Although the present State Coal Mine Inspector's records list the M. M. and P. mine in the S½ sec. 19, the only possible coal mine site found in a brief field check by the present author in June 1973 is in the location shown above, in the NW¼. Also, a 1911 report by Mortimer A. Sears of the General Land Office (presently U.S. Bureau of Land Management) and Max W. Ball of the U.S. Geological Survey described an abandoned mine in the NW¼ sec. 19. Accordingly, it is here inferred that the M. M. and P. mine was opened in 1936(?) at

the site of the old mine. This mine was first opened before 1909, as indicated by Sears' and Ball's report. Their description follows in its entirety:

> Down the gulch southwest from the Mosby mine about a half mile, is an abandoned coal mine or prospect, which, judged from the size of the dump, was of some considerable extent. At the time of Sears' and Ball's visit it was so completely caved that no measurement of the coal could be obtained. Ball managed to get his head in far enough to see good coal at the top of the square set timbers. The roof is fire clay. This coal has been reported to Sears as being 6 or 7 feet in thickness. Mr. Mosby has stated to Sears that he considers this a better grade of coal than that in the Mosby mine. The dip is estimated to be 2° or less to the north. This bed is, therefore, probably in the neighborhood of 100 feet stratigraphically below the Mosby bed.

All that remains of this mine, on the surface, is a small scooped-out area south of a hill of bedrock (moderately soft sandstone), and some coal and other fragments in a low mound to the south. Exposures are too poor to determine if "fire clay" overlies the coal bed here, as mentioned above by Sears and Ball. Information in the State Coal Mine Inspector's Office is as follows:

M. M. and P. mine (latest name), S½ sec. 19, T. 13 S., R. 61 W.
No map.
Latest operator: Pete Mandarich
Rock tunnel 50 feet, drift 230 feet, 54-inch-thick bed

Production:	Year	Tons
	1936	55
	1937	15

Mosby's mine: NW¼NE¼SE¼ sec. 18, T. 13 S., R. 61 W., El Paso County.--This mine is one of the best documented ones in the old reports. In August 1910, G. B. Richardson and C. W. Cooke of the U.S. Geological Survey visited this mine and the surrounding area. They mapped the approximate location of the coal bed of this mine for about 5 miles and the top of the lignite zone for about 1 mile. Also, they measured and sampled the coal and briefly described the mine. On July 10, 1911, Mortimer A. Sears sampled the coal. On September 14, 1911, Sears and Max W. Ball visited the mine, measured the coal bed, and briefly described the mine. The following material is taken from their reports.

The mine was opened in January 1909, by Mr. J. M. Mosby, who is the only recorded operator. Richardson wrote that the shaft was 40 feet deep and that the following section was measured 30 feet north of the foot of the shaft:

Section in Mosby's mine:	Feet	Inches
Coal	1	2
Parting	---	1
Coal	1	6
Parting	---	3
Coal	1	8
Total coal----	4	4

Richardson also stated that "the coal is subbituminous and disintegrates rapidly on exposure to the air." Analysis of his sample is shown on page 12; Mosby informed Sears and Ball that Richardson's sample "was taken 50 feet east of the shaft."

Until just before Sears and Ball visited the mine in 1911, it had been worked through a shaft, "but at the time of this visit an incline had been driven, starting a few feet above the coal horizon and connecting with the drift about 20 feet north from the foot of the shaft." Dip of the bed was said to be "almost due north, 4 feet to the hundred," or about two degrees.

Sears and Ball measured the part of the coal bed being mined (same part as given in Richardson's section, above) "in a room turned east from the north drift." They measured "4 feet 11 inches of coal with no distinct partings and all clean coal, although the upper 2 feet appears much brighter than the lower portion." Just above the mined portion of the bed in the new incline, they measured a section that is described as follows:

Section measured by Sears and Ball (Mosby's mine)

	Inches
Sandstone, roof	
Shale, brown----------	3/4
Coal----------	3/4
Shale, brown----------	3/4
Coal----------	5/8
Coal, dirty, and shale----------	1-1/2
Coal----------	3-3/4
Sandy shale parting----------	3-1/2
Coal----------	2-1/2
Shale and coal----------	2-1/4
Shale, brown, with little coal----------	5-1/4
Coal----------	1-1/2
Shale----------	3-1/2
Coal----------	3
Shale parting----------	3-1/2
Coal----------	5/8
Sandstone and coal----------	2-1/2
Coal----------	2-1/2

Section measured by Sears and Ball (Mosby's mine)--Continued

	Inches
Sandstone and coal	3/8
Coal	1/8
Sandstone and coal	1/2
Coal	5-1/4
Sandstone parting	3/8
Coal	1/4
Sandstone parting	1
(Portion of bed being worked)	4 feet, 11 inches

Sears and Ball took a sample of the mined part of the bed 150 feet north of the shaft. Their report on this sample is as follows:

> The analysis furnished by the Bureau of Mines gave only results as received and as computed to dry coal, giving neither air-dried results nor air-drying loss. The air-dried column below is computed by using the air-drying loss in the sample obtained by Richardson * * *.

Analysis of coal from Mosby mine (in percent)
(Air-dried computation on the basis of air-drying loss of sample obtained by Richardson, 20.8%; other sampling by Sears)

	As received	Air dried	Dry coal
Moisture	32.8	15.2	--------
Volatile matter	30.2	38.1	44.9
Fixed carbon	24.2	30.6	36.1
Ash	12.8	16.1	19.0
Sulfur	0.45	0.57	0.65
Btu	6,720	8,485	10,000

Possibly, the slightly better quality of Sears' and Ball's sample is partly a result of sampling at a greater depth, farther from the effects of weathering.

In June 1973, the present author visited the site of the old mine with the landowner's son, Jack Vorenberg, and noted an opening only three feet in diameter appeared to mark the incline that is mostly caved. About 125 feet north of this is a circular area of slumping(?) about 30 feet in diameter and about 3 feet in depth that may mark the old shaft. Just north of the slumped(?) area, a 6-inch pipe set in concrete may be an old air hole for the mine; a rock dropped into this pipe indicated a depth of approximately 50 feet, with deep water at the bottom.

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Test No. .....

CHEMICAL LABORATORY REPORT.

Lab. No. 10732

Sample of Colorado coal — Can No. 9 111

From State of Colorado — Investigation economic geology

County El Paso — Section M.R.Campbell

Town Calhan — Collector G.B.Richardson

Mine Mosby — Operator J.A.Mosby

Bed of coal Mosby — Location in mine .....

Method of sampling usual — Gross weight, 40 lb. Net weight, ...

Air-dry loss 20.80 - Date of sampling August 3,1910. Date of analysis 9/1/10

		Coal (Air dried)	Coal (As received)	Coal (Moisture free)	Percentages recalculated (Moisture and ash free)
Proximate Analysis	Moisture	15.57	33.13		
	Volatile matter *	32.77	25.95	38.81	48.98
	Fixed carbon	34.12	27.03	40.42	51.02
	Ash	17.54	13.89	20.77	
		100.00	100.00	100.00	100.00
Ultimate Analysis	Hydrogen	5.27	6.48	4.19	5.29
	Carbon	47.03	37.25	55.70	70.30
	Nitrogen	.86	.68	1.02	1.29
	Oxygen	28.92	41.40	17.87	22.55
	Sulphur	.38	.30	.45	.57
	Ash	17.54	13.89	20.77	
		100.00	100.00	100.00	100.00
Calorific value determined	Calories	4348	3444	5150	6500
	British thermal units	7826	6199	9270	11700
Calorific value calculated from ultimate analysis	Calories		3465		
	British thermal units		6237		

*Modified volatile

Date, September 3, 1910. (Signed) M.R. Campbell, Chem

Form T. B. 135.
Ed. 4 10-5-10.

Production from this mine is unknown. However, Sears and Ball (1911) reported that "Mr. Mosby has stated to Sears that he sold 600 tons of coal in 1909, keeping five men busy during the winter season and one man busy through the summer season."

Unnamed mine: SW¼NW¼NW¼ sec. 30, T. 11 S., R. 60 W., El Paso County.--An original map by G. B. Richardson, C. W. Cooke, and R. H. Wood, scale 1:31,680 and dated 1910, shows this mine only with a symbol and the label "Old Shaft." A coal bed outcrop is shown just north of the mine. No other data are given. Richardson, in a report of 1910, called this an "abandoned shaft." Another old planimetric map at 1:125,000 scale shows the coal outcrop with a "4' coal" label, and shows the mine with these notations: "Reported 14' coal" and "Shaft 60'." However, the location shown was W½SE¼NW¼ sec. 30.

Dane and Pierce (1936, p. 1323) mentioned this mine and showed the following stratigraphic section, exposed "in an old mine":

	Feet	Inches
Roof, shale and bony coal		
Coal, in streaks, dirty-----	1	9
Parting, clay and bone------	-	4
Coal----------	4	4
Floor, shale, brown		

Purdon mine: NW¼NW¼SE¼ sec. 27, T. 11 S., R. 61 W., El Paso County.--This mine was opened during or before 1909 by Mr. H. W. Purdon. In the summer of 1909, Marcus I. Goldman of the U.S. Geological Survey took a sample from this mine and gave an analysis of it (Goldman, 1910, p. 338, Lab. No. 7128) showing, on an as-received basis, Btu 6,060; ash, 13.9 percent; and sulfur, 0.1 percent. The sample was from 21½ inches of the coal.

The map by Richardson, Cooke, and Wood cited above shows this mine with a measured section of 6 feet 9½ inches of coal. In an unpublished report, Richardson says the following about this mine:

> The coal is a low grade, subbituminous variety which disintegrates rapidly on exposure to the air. A sample from a fresh surface of the Purdon slope, 700 feet from the entrance, gave the following results on an air-dried basis:

Analysis of coal[1] from Purdon's mine

Laboratory number	:10741
Air-drying loss (in percent)	:25.20

	Coal air-dried
Moisture	11.3%
Volatile matter	31.4%
Fixed carbon	33.0%
Ash	24.3%
British thermal units	7,362

[1]Thickness of coal represented by sample, 6 feet 6 inches.

The high percentages of ash and air-drying loss are noteworthy. The high ash content is due to the fact that this coal is very "dirty." The coal is intimately seamed with minute partings of noncombustible matter.

The low heat value requires a minimum thickness of 45 inches for the bed to be classed as workable. It is questionable whether any of this coal at present or in the near future can be worked profitably. H. W. Purdon operates his mine in a desultory fashion, only digging out coal when a purchaser drives up for a load. The people in the town of Ramah, in sec. 1, prefer to pay more for coal shipped in on the railroad rather than use the low-grade coal from Purdon's mine.

The following measurements of the coal at the localities indicated emphasize its "dirty" character and low grade.

Section of coal in NW¼SE¼ sec. 27, immediately west of Purdon's mine, T. 11 S., R. 61 W.

	Feet	Inches
Shale		
Coal		4
Shale, sandy		4
Coal	1	5
Coal and shale		3
Coal		8
Sandstone		1
Coal, laminated with sandy shale	1	4
Shale and sandstone laminated with coal		5
Coal streaked with sandy shale	1	8

Section of coal in SW¼SW¼ sec 22, T. 11 S., R. 61 W.

	Feet	Inches
Coal, shaly		5
Coal		6
Coal, sandy		2
Sand		2
Coal	1	1½
Sand, clay and impure coal		7
Coal with 1-inch parting, carbonaceous shale in middle		5¼
Sand and carbonaceous shale		6
Coal with two sandstone partings, each 1/8-inch thick	1	4
Coal, 3/4-inch sandstone at top		5
Clay, yellow and sandy		1½
Coal		5
Sandstone, yellow, shaly, with partings of coal		6
Coal laminated with shale		6
Shale, sandy		1
Coal with one sandy parting 1/4-inch thick		11
Shale, brown, sandy		8½
Coal with thin seams of clay		2½
Coal		5½

George (1937, p. 160) says that Richardson measured and sampled the coal bed in the Purdon mine on August 15, 1910, and says that the section was as follows:

Laboratory number		:10741
	Feet	Inches
Roof, sandy shale:		
Coal	1	0
Shale, sandy		1½[a]
Coal, with 5 partings, each less than 1/8-inch thick	2	8
Shale, sandy, and coal		2[a]
Coal, with 3 partings, each less than 1/8-inch thick	2	10
Floor, not stated:		
Thickness of bed	6	9½
Thickness of sample	6	6

[a]Not included in sample.

George (1937, p. 64, 65) shows analyses of the samples collected by Goldman and Richardson, as follows:

Sample		Proximate (percent)				Ultimate (percent)					Air-drying loss (percent)	Calorific value		Softening temperature (Degrees F.)
Condition[a]	Laboratory number	Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen		Calories	British thermal units	
1	7128	34.4	24.4	27.3	13.9	.1	6.5	35.9	.7	42.9	26.4	3,367	6,060	
2			37.3	41.5	21.2	.2	4.0	54.8	1.0	18.8	----	5,128	9,230	
3			47.3	52.7	----	.3	5.1	69.5	1.3	23.8	----	6,506	11,710	
1	[a]10741	33.7	23.5	24.6	18.2	.3	6.3	33.2	.5	41.5	25.2	3,061	5,510	2,510
2			35.4	37.1	27.5	.5	3.9	50.1	.8	17.2	----	4,611	8,300	
3			48.7	51.3	----	.7	5.3	69.0	1.1	23.9	----	6,356	11,440	

[a]Condition:

1. As-received.
2. Dried at temperature of 105°C.
3. Moisture- and ash-free.

Unnamed mine: SE¼NE¼NW¼ sec. 34, T. 6 S., R. 62 W., Elbert County.--The only records found for this mine are notations on an old 1:125,000-scale planimetric map. This map showed a mine symbol on the outcrop of a coal bed, with the notations "Coal Mine, 6 foot coal."

This mine probably was worked only for local use and only for a short period of time, probably before 1910.

Unnamed mine: C NE¼NE¼ sec. 35, T. 5 S., R. 62 W., Arapahoe County.--Little information has been found regarding this coal mine. The old unpublished 1:125,000-scale planimetric map shows a mine symbol in this location, with the notations "Coal Mine, 30-inch coal."

Two unsigned pages in a file for this township give the following information: (1) Mortimer A. Sears is quoted as saying that about one-fourth of a mile northeast of SE¼ sec. 34 "there is a country coal bank where nearby ranchers secure coal, showing a coal seam having a thickness of 29 inches." (2) The second page had the following:

NE¼ sec. 35	Mine	Dirt roof		
		Coal and shale		5 inches
		Fireclay		4 inches
		Coal	2 feet	5 inches
		Shale floor.		

Fondis mine (Janner mine): SE¼SE¼ sec. 29, T. 9 S., R. 62 W., Elbert County.--This mine is referred to in all older reports as the Janner mine, from Mr. Joseph Janner who apparently was the earliest legal operator.

Joseph Janner, on May 14, 1913, applied to purchase the surface of the tract including the future mine site. On November 10, 1914, a resident of Fondis made a written complaint that a Mr. Carl J. Erickson was digging coal on Federal Government land. A "Special Agent Leuenberger" made an investigation of this complaint on November 25, 1914. The following account of Erickson's work is apparently from Leuenberger's report:

> Erickson has driven an inclined tunnel for 90 feet reaching a depth of 30 to 35 feet below the surface. The coal is covered by about 20 feet of unconsolidated deposits of late geologic age. Below this, the following formation occurs going down as revealed by the walls of the tunnel:

	Feet	Inches
Coal----------		2
Shale----------		6
Coal----------		6
Shale----------		4
Coal----------	1	0
Shale----------		6
Coal----------		10
Shale----------		2
Coal----------		5
Shale----------		6
Coal----------	1	0
Shale----------		2
Coal----------	1	0
Shale----------		2
Coal----------		2
Shale and coal----------	1	6
Coal----------	2	6

> The surface of the land slopes toward and into Kiowa (actually West Bijou) Creek. The tunnel slopes from north to south. At the southern extremity Erickson has tunneled eastward about 20 feet, and westward about 10 feet. The coal is a lignite, and slacks when exposed to the atmosphere. In doing this development work, Erickson has taken out about 50 tons of coal which he has sold to settlers in the neighborhood of $1.50 per ton. He has a very crude homemade equipment with which he takes out the coal. He has applied to the local land office to buy this coal land, but was advised that the same had not been classified though withdrawn for that purpose.

Records in U.S. Geological Survey files show numerous inspections of the mine were made between 1923 and 1941. These records detail various aspects of the operations through the years. The records are for coal licenses of Joseph Janner (Coal License Denver 027947), and G. (Giaconto) Battaia (Coal Lease Denver 040594). Janner operated the mine from about 1921, and a miner named C. F. Jenks worked it for Janner until April 1, 1925. Jenks took production records with him when he left to work in metal mines at Victor, Colo., so that production from November 28, 1924, until April 1, 1925, is unknown. On March 23, 1926, Mr. Battaia took charge of the property as miner. Janner's license expired on June 29, 1928, and Battaia applied for and received a coal lease (Denver 040594). Mining operations ended in December 1937. Prices reportedly paid (per ton) for the coal by residents of Fondis and vicinity are: $1.50 in 1923, $2.40 in 1924-1926, $2.00 in 1928-1930, and $1.50 in 1935. In the early 1930's, miners were paid $0.25 per ton for their work.

Mining methods are described in the various reports cited above. The earliest reports available, by C. L. Duer in 1923-1924, are excerpted as follows:

> Opening 64 feet south of north line and about 495 feet east of west line (of SE¼SE¼, sec. 29). Slope 70 feet long to coal. Entry driven due south in coal 250 feet. Two rooms turned on west side of entry and four rooms on east side of entry. Air shaft 30 feet deep connects with second room on east side of entry. Rooms 12 to 15 feet wide with about same width of pillars. First room on west side abandoned because water was found - room about 30 feet in. Coal 6 feet in thickness.

The slope is shown on a map to have a dip of 20° but a report of September 10, 1937, gives a dip of 26°.

In 1926, Battaia purchased rails, steel cable, and four small mine cars, each of which held about 1,000 pounds. Later reports indicate these cars, rather than scales, were used to record production. A report of June 3, 1927, by C. L. Duer included the following statements:

> The mine was in good physical condition on date of examination. The ventilation was good; no gas has ever been found; open lights are used, and the small amount of coal mined is shot off the solid with black powder. A fair supply of timber was on hand. Little, if any, coal will be mined during the summer.

A report of January 6, 1928, by Duer, indicated that no timber was used in either rooms or entry, but "at the bottom of the slope the continued exposure to the air has caused the coal in the roof to slack and some of it began to slough off. This part of the entry has been crossbarred and lagged... No explosive gas has ever been found or reported in this property..." The same report includes the following measured section :

	Feet	Inches
Coal roof		
Coal----------	0	9
Sandstone----------	0	1
Coal----------	0	3
Sandstone----------	0	0-3/4
Coal----------	2	9
Bone----------	0	0-½
Coal----------	1	3
Bone----------	0	3½
Coal----------	1	0
Shale floor.		

Dip of strata - 2° N., 75° W.

On September 13, 1923, Duer measured and sampled (analysis number 94618) as follows:

	Feet	Inches
Shale roof		
Coal----------	2	8
Coal----------	4	8 (Analysis 94618)
Shale floor.		

On November 22, 1928, Duer measured and sampled (Laboratory number A47114) the lignite at the face of room 17 (room 8, east side of tunnel, in Bourquin's 1932 map, fig. 2):

	Feet	Inches
Roof, coal		
Coal----------	1	2
Sandstone----------	0	0-½
Coal----------	0	1½
Sandstone----------	0	0-½
Coal----------	0	9
Clay----------	0	2
Coal----------	0	5
Sandstone----------	0	0-¼
Coal----------	0	11¼
Sandstone----------	0	0-¼
Coal----------	1	9
Sandstone----------	0	0-½
Coal----------	1	0
Floor, shale		
Strata, horizontal.		

The two analyses are shown in the report by George (1937), as follows:

Sample		Proximate (percent)				Ultimate (percent)					Air-drying loss (percent)	Calorific value		Softening temperature (Degrees F.)
Condition[a]	Laboratory number	Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen		Calories	British thermal units	
1	94618	33.5	27.2	22.1	17.2	.4	6.3	34.5	.7	40.9	14.3	3,256	5,860	2,480
2			40.8	33.3	25.9	.6	3.9	51.9	1.0	16.7	----	4,889	8,800	
3			55.1	44.9	----	.8	5.3	70.0	1.3	22.6	----	6,594	11,870	
1	A47114	30.9	29.1	25.3	14.7	.5	6.5	38.4	.7	39.2	9.7	3,722	6,700	2,530
2			42.1	36.6	21.3	.7	4.5	55.6	1.0	16.9	----	5,383	9,690	
3			53.5	46.5	----	.9	5.7	70.6	1.3	21,5	----	6,833	12,300	

[a]Condition:
1. As-received.
2. Dried at temperature of 105°C.
3. Moisture- and ash-free.

In 1931 or 1932, C. H. Dane and W. G. Pierce visited the mine and they discussed the two analyses and measured sections (Dane and Pierce, 1936, p. 1,323). According to them, number 94618 was from face of the main entry, 375 feet from the opening. For number A47114, taken "270 feet from the bottom of the slope," they indicate a coal floor with an estimated thickness of 12 feet 6 inches for a total coal-bed thickness of 18 feet 9½ inches.

Mining was carried on mostly in the months of September to May because of the seasonal local market for the coal. The face was driven due south, with rooms turned east and west from the tunnel. However, in May 1929, water about 10 inches deep was standing on a parting about 60 feet long at the foot of the slope, "and all rooms turned west encounter water after being driven a short distance" (Cuthbert C. Mather, Inspection Report, May 16, 1929). Most of the development was in rooms east of the tunnel, possibly because of water being more prevalent on the west side. One report stated that the coal was better on the west side, whereas another said that the bed was thicker on the east.

A report of December 31, 1932, by J. J. Bourquin of an inspection made by him on November 11, 1932, remarks on the great amount of fine coal that "is gobbed with other waste material in the rooms. Operation of the mine could not continue if the gobbing of that fine coal were prohibited." Bourquin prepared a map that is included in the present report (fig. 2). A slightly later map of March 26, 1935, by F. W. Calhoun, is the latest map available and is therefore included in the present report (fig. 3). Sections measured by Bourquin and other descriptions given in his report are as follows:

	A		B	
	Feet	Inches	Feet	Inches
Roof----------	Shale		Coal	2-3
Coal----------	1	2	1	1
Shale----------	0	0-3/4	0	0-½
Coal----------	0	2	0	3
Shale----------			0	1
Shale and coal-----	0	2	---	
Coal----------	0	8-3/4	0	1
Shale----------	0	1	0	0-1/4
Coal----------	0	4½	0	8
Shale and bone----------			0	2½
Shale----------	0	1	---	
Coal----------	2	5	1	4
Bone----------			0	3
Coal----------			1	0
Floor----------	Shale		Coal	
Total thickness of bed measured----------	5	3	5	0-1/4
Total thickness of coal measured----------	4	10-1/4	4	5

Section A measured at face of No. 9 room, off right side of main entry. Section B measured at face of No. 1 room off left side of main entry extended beyond air-course.

A glance at the measured sections of the coal bed recorded above gives one an understanding regarding the source of the great amount of fine coal that is gobbed in the mine. The numerous shale bands in the coal bed disintegrate badly after having been broken down in mining and the thin bands of coal--a poor quality of subbituminous coal--disintegrate with the shale. The amount of waste material in the coal bed is so great that it would be quite impossible, from an economic point of view, to load the waste out of the mine. The mine is very dry in all parts except in rooms No. 1, 4, and 5 on the right side of the main entry. Water was standing in those rooms and it was impossible to determine the lengths to which they had been driven.

Figure 2.- Map of the Skinner (Fondis) coal mine, November 11, 1932, by J. J. Bourquin.

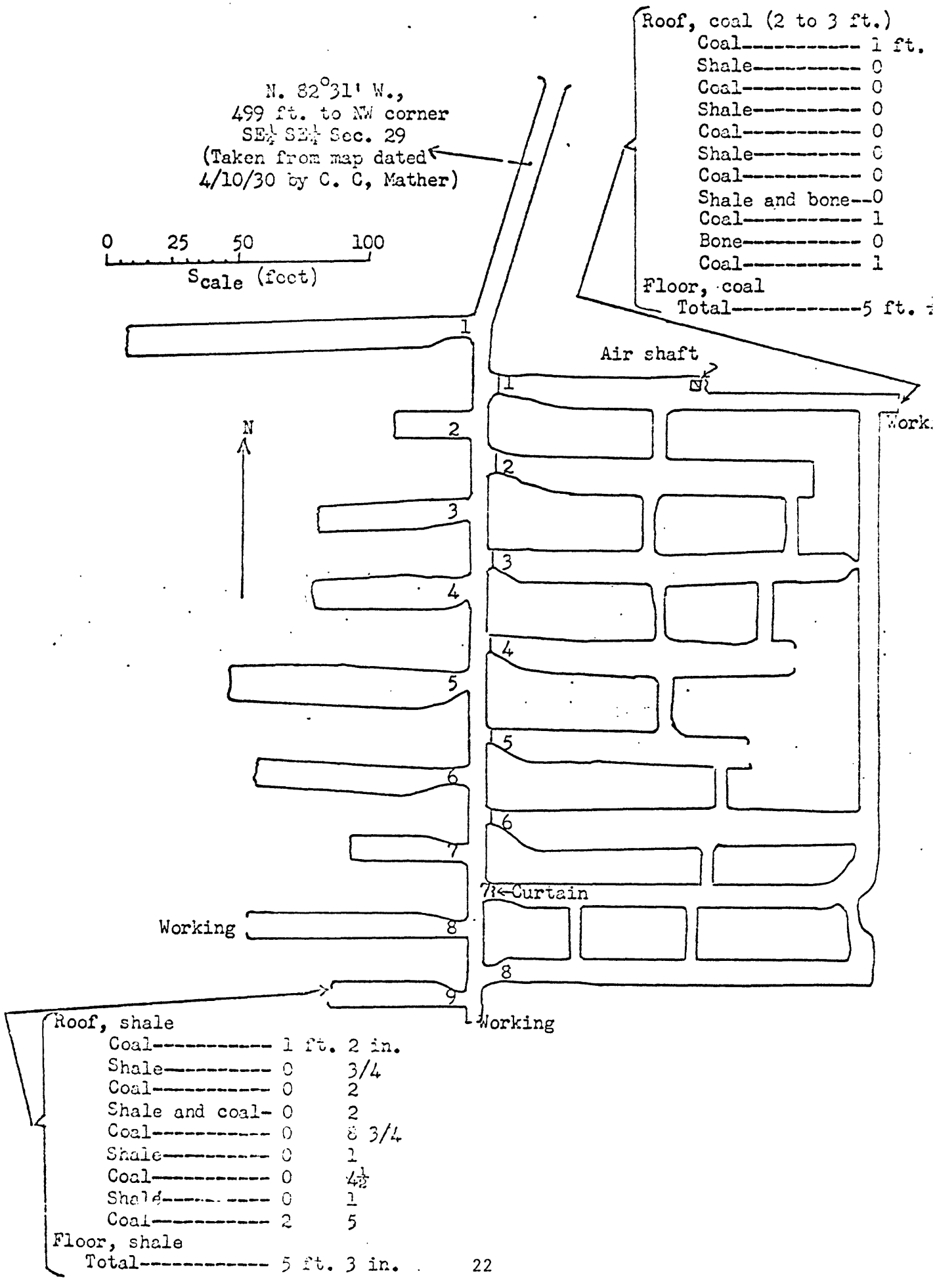
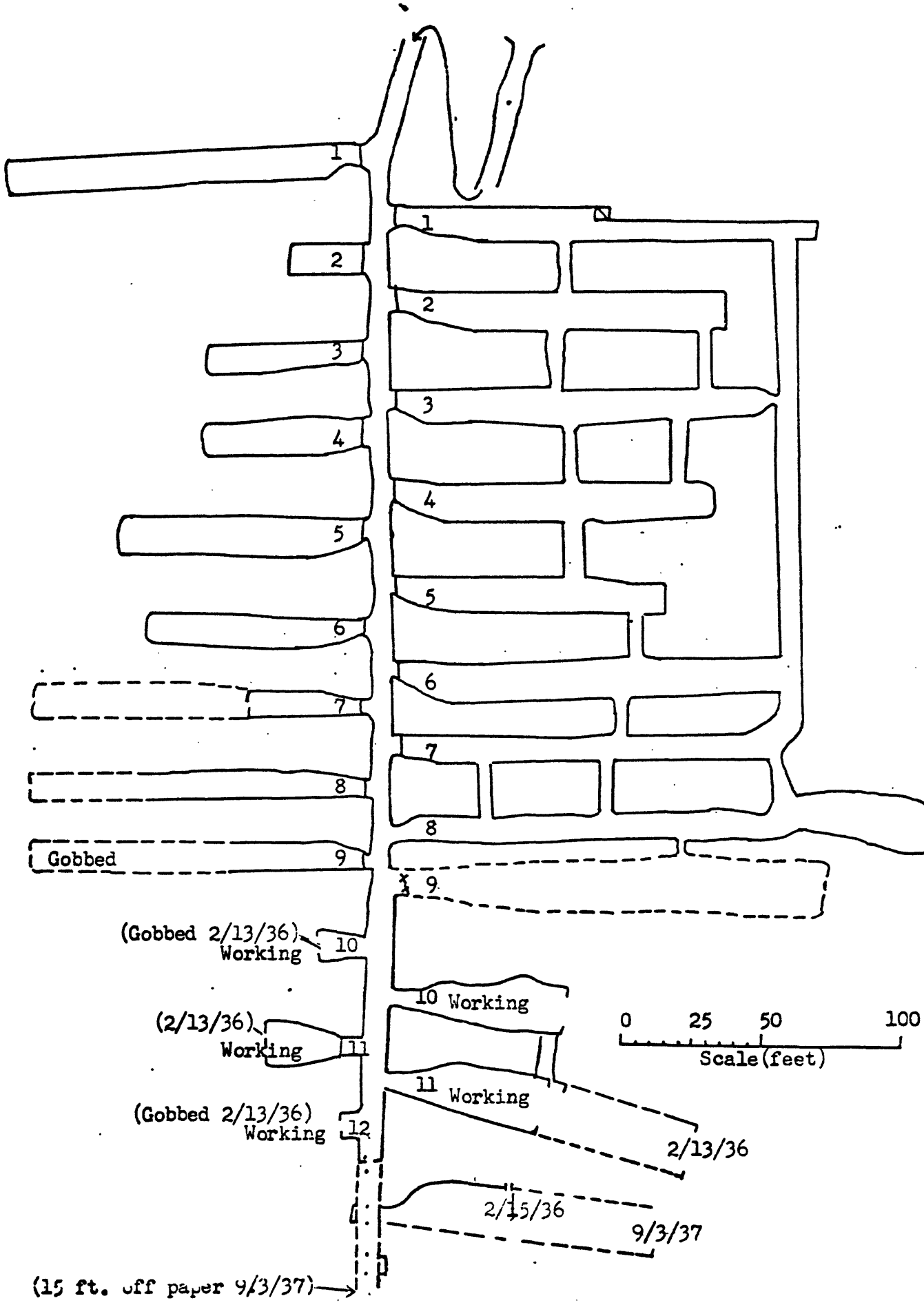


Figure 3.- Map of the Fondis coal mine, March 26, 1935, by F. W. Calhoun.



On March 26, 1935, F. W. Calhoun made an inspection of the mine and described and measured the coal bed as follows:

> The coal is a very poor lignite dull in lustre and the seam contains many partings of sand and bone coal. The following coal section measured at room neck No. 12 on west side of main entry is typical of the part of mine now being worked and is probably a close average of all prior workings:

	Inches
Roof, sandy shale	
Coal	13½
Sandstone	0-½
Coal	2½
Sandstone	0-3/4
Coal	1¼
Sandstone	0-¼
Bone	2½
Coal	5
Bone	3
Coal	6
Sandstone	0-½
Coal	8
Sandstone	0-¼
Coal	7
Sandstone	0-¼
Coal	14½
Sandy bone	5
Coal	10
Floor, fire clay	
Total coal	67-3/4 inches
Total bone	10½ inches
Total sandstone	2½ inches
Total seam	80-3/4 inches

December 1937 is the last month in which the mine was operated. A report of April 1939 stated that "the portal of the rock slope was caved. . . due to breakage of timbers at the portal under the load of wet top soil and roof. . ." The caved portal was reopened by unknown persons between August 1940 and September 1941; the underground workings were not examined in the September 1941 inspection because of inadequate ventilation. The last inspection made, on June 6, 1953, showed that "the air shaft has been filled to within 5 feet of the top of the ground, and the slope to within 8 feet of the top of the ground respectively with dirt from material erosion during the past years."

Records of production from the Fondis mine are incomplete. Some figures are available from the records of the U.S. Geological Survey that are not in the State Coal Mine Inspector's Office records, and vice versa. Consolidation of these records show the following product-

ion, in short tons (a query indicates years for which there was production but it is unknown; a + sign indicates greater production in a year with incomplete records):

Year	Production (Rounded)
1921	356
1922	645
1923	410
1924	349+
1925	63+
1926	157+
1927	337
1928	428
1929	430
1930	261
1931	?
1932	?
1933	237
1934	270
1935	297
1936	149
1937	20
Total production-----	4,409+

Valley mine: NE¼SW¼NE¼ sec. 19, T. 9 S., R. 62 W., Elbert County.--No information on this mine has been found in the published or unpublished literature except for the following from the State Coal Mine Inspector's Office:

Valley Mine
Sec. 19, T. 9 S., R. 62 W.
Subbituminous coal

Latest operator: Harry E. Blay, Calhan
Slope, 30 feet long, 20% pitch
4-foot 6-inch-thick bed

Production

Year	Tons
1936	200
1937	25

The present writer found the site of an old mine, presumably the Valley mine, in the location given in the heading above, with the aid of one of the present landowners, Mrs. O. O. Harvie, and her son Stephen. The filled-in entrance to a slope(?) mine is still visible on the north side of a lightly wooded knoll in a valley tributary to West Bijou Creek. Bright black vitrain along with dirty lignite and carbonaceous shale fragments were found on a small dump outside the

entrance. The lignite bed, which does not crop out because of the extensive cover of Quaternary sediments around the knoll, is at the top of the lignite zone. A coal prospecting drill hole about three-fourths of a mile to the northwest indicates an 11-foot-thick lignite bed 96 feet below the surface that probably is this same bed.

Stander mine: NE¼SE¼NE¼ sec. 2, T. 9 S., R. 62 W., Elbert County.-- This was a small mine that operated from 1934 to 1940, with one to three men working at a time. A fire beginning in October 1939 finally forced its abandonment in November 1940. A small quantity of lignite from the outcrop close to this mine accounts for the 1940 production shown.

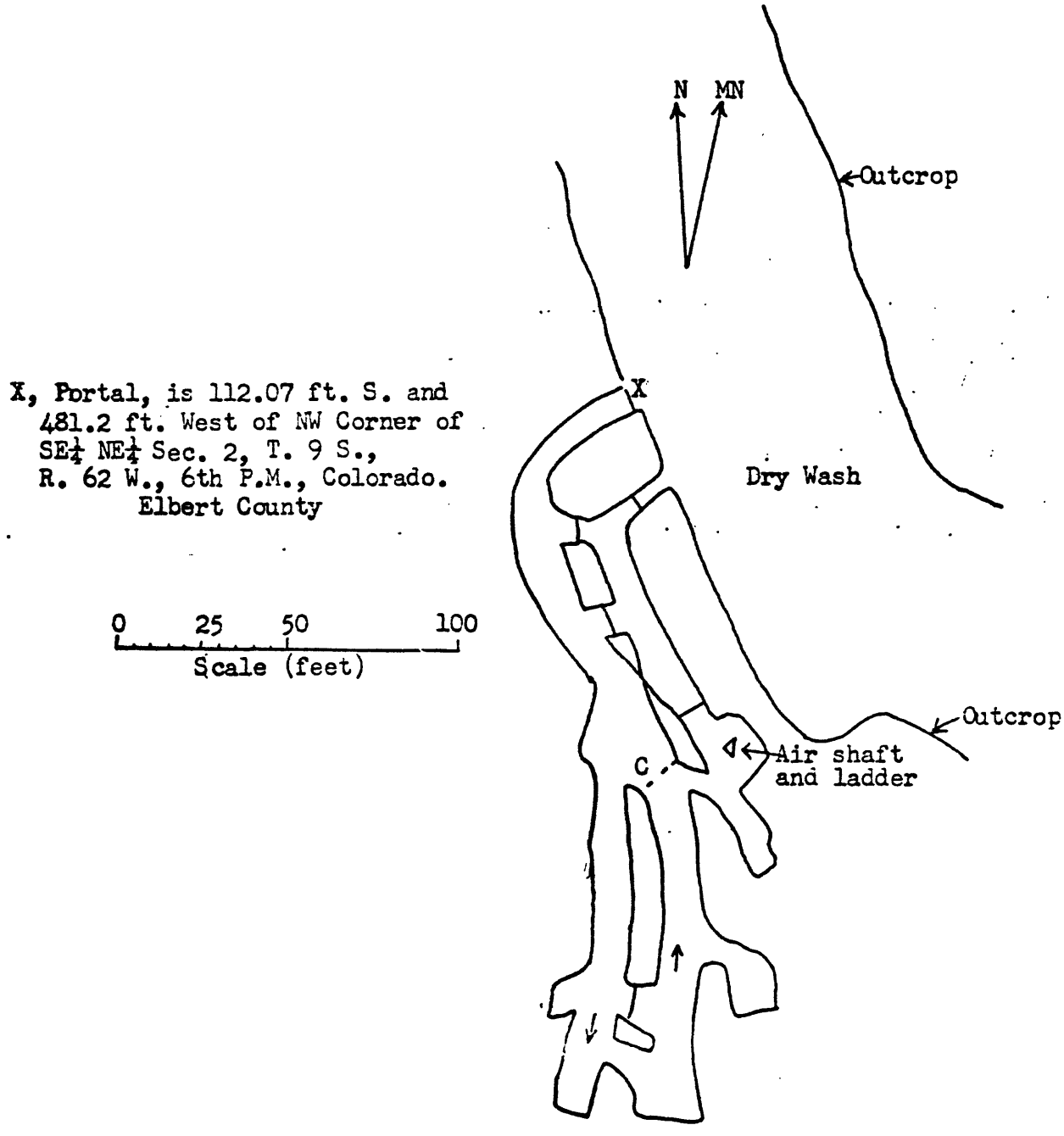
The first inspection of the mine was by F. W. Calhoun on March 16, 1935. A photocopy of a map by Calhoun is included here (fig. 4). Part of his description is as follows:

> The seam was opened at the outcrop in a wash and the workings have meandered south, east, and west to keep out of water. The dip is probably 2% to the west. The work to date has been largely parallel to and not over 100 feet from the outcrop at any place. The aircourse has been filled with weathered coal, rock, and bone, and an airshaft has been raised 19 feet to the surface . . . Two men work at the mine. The mine car is pushed by the men underground and is pulled by horses up a short steep incline outside to the tipple dump. The coal is delivered from the face 40 feet to end of track in a wheelbarrow where it is loaded in the mine car and hauled 160 feet to the tipple over steel rail track. The roof is timbered in good order, and the entries are driven not over 11 feet wide . . . The coal is lignite of very poor quality, soft and dull gray in color. The following is a section measured in the aircourse 30 feet inbye the center of the airshaft:

	Inches	
Roof, soft shale		
Coal----------	18	
Bone----------	3	
Coal----------	1-3/4	
Sandy iron sulphide------	½	
Coal----------	6½	
Shale----------	2½	
Coal----------	36	
Floor, black shale		
Total coal----------		62¼ inches
Total refuse----------		6 inches
Total seam----------		68¼ inches

Progress in the mining is further detailed by F. W. Calhoun in an Inspection Report, dated September 1, 1936, for an examination he made on February 13, 1936. Most of his report is as follows:

Figure 4.- Map of the Stander mine, March 16, 1935, by F. W. Calhoun.



The mine was in operation by two men underground and one man and a horse outside. No horses are used underground. The mine is opened from the outcrop at which place the base of the coal seam is on the level of the bottom of the dry wash. The horse is used to pull the car up to the tipple dump, which is raised high enough for mine cars to be dumped into trucks. The miners are paid 75 cents per ton for mining and delivery of coal to trucks at the surface.

The mine is damp throughout, but no standing water was noted in the mine. No rock dust is used in the workings. An escapeway has been provided in the airshaft through the installation of a substantial ladder. The mine roof is very dangerous and must be timbered more heavily than heretofore. Three roof caves have occurred which have caused a great deal of trouble. Approximately six inches of coal is left up for roof protection, and about 62 inches of the seam is mined. The coal is a very poor grade lignite, is soft, and is dull gray in color.

Calhoun made another inspection on March 11, 1938, indicating similar work in progress. However, on April 13, 1939, when Calhoun next visited the mine he found that the arroyo outside the portal had a flowing stream and that the inside of the mine was flooded. On this occasion the mine was not examined. Calhoun noted that the mine had apparently not been operated for several days. In the last inspection during mining operations, on April 30, 1939, Calhoun gave the following description:

The operations of the mine for the past year have been confined to advancing the one room driving in a slightly southwest direction from the main entry, and the turning of a room neck from the west side of the main entry. The ribs of the room neck are located 18 and 24 feet respectively outbye the neck of the first mentioned room. This room has been advanced 110 feet during the past coal season, or 192 feet inbye the entry rib, and at the time of the examination was 26 feet wide at the face.

The coal is blasted from the solid with No. 2 pellet powder and fuse; adobe is used for the stemming of shots. The coal is loaded into tram cars and hand-trammed to the foot of the hoisting slope where it is pulled to the surface by a horse. Carbide lights are used for illumination. Two mine cars are in use. One miner is employed underground.

The mine is equipped with a hand pump for dewatering the mine. On the date of the inspection, the main entry was flooded with about 15 inches of water from the portal to a location about 60 feet inbye the portal, and the floor was wet from

the aforementioned location to the neck of the room driving west, and to a location about 75 feet inbye the neck of this room, in the room.

The main entry is timbered with 3-piece sets, spaced about 5 feet apart. Track is laid along the left rib of the room looking towards the face. The room is timbered with two rows of posts placed along the right side of the track. The posts are spaced about 6 feet apart in each row, and the rows are spaced about 7 feet apart. Additional posts are placed along the right rib of the room where necessary.

Measurement of the coal by Calhoun at the time of this last inspection is quite similar to the earliest measurement. This latest one was made "at the face of the room on the right or west side of the main entry 192 feet inbye the room neck" and is as follows:

	Feet	Inches	
Roof, hard bony or carbonaceous shale			
Coal----------	1	7	
Sandstone----------	0	2	
Coal----------	0	9	
Bony, soft----------	0	1½	Practically level
Coal----------	1	5½	
Bony, hard----------	0	8	
Coal----------	0	8	
Floor, bony			

Fire was discovered in the mine by Mr. Stander on October 16, 1939, and reported to the Geological Survey on October 19, according to an inspection report of October 30, 1939, by F. W. Calhoun. Calhoun accompanied Stander and others in attempting to control the fire. On his first day at the mine fire on October 20, Calhoun found, also, "two caved areas which extended from the mine to the surface." These caved areas were due to fire. Calhoun asserted that "the fire was apparently from spontaneous combustion" and wrote that on October 21, "The only fire noted was in the gob, about 180 feet inbye the haulage portal in the second room neck on the right or west side of the main haulage." Calhoun examined the mine and fire on October 23, 24, 27, and 28, 1939, and his report of October 30 describes attempts to control the fire.

J. J. Bourquin and J. D. Turner of the Geological Survey examined the mine fire on October 30 and 31, 1939, and Bourquin described the scene in his report dated November 2, 1939. Bourquin cited "smoke belching from two caved areas on the surface which areas are believed to be over the two rooms at the extreme southern end of the mine* * *," and "from the collar of the air shaft * * *." Bourquin and Turner directed and helped in work to build stone and adobe walls inside the mine to contain the fire, and tamped dirt in surface caves and cracks. On November 3, 1939, Bourquin and Turner returned to the mine, and

Bourquin (Inspection Report, Nov. 4, 1939) said he believed the fire was under control. However, late in November the fire burned around the masonry seal (J. D. Turner, Inspection Report, Dec. 7, 1939), and the decision then was made to seal the portal of the mine; this sealing was completed on November 23. "A very small volume of smoke was observed at the caved areas on the surface about 220 feet south of the main portal * * *" at this time, according to Turner.

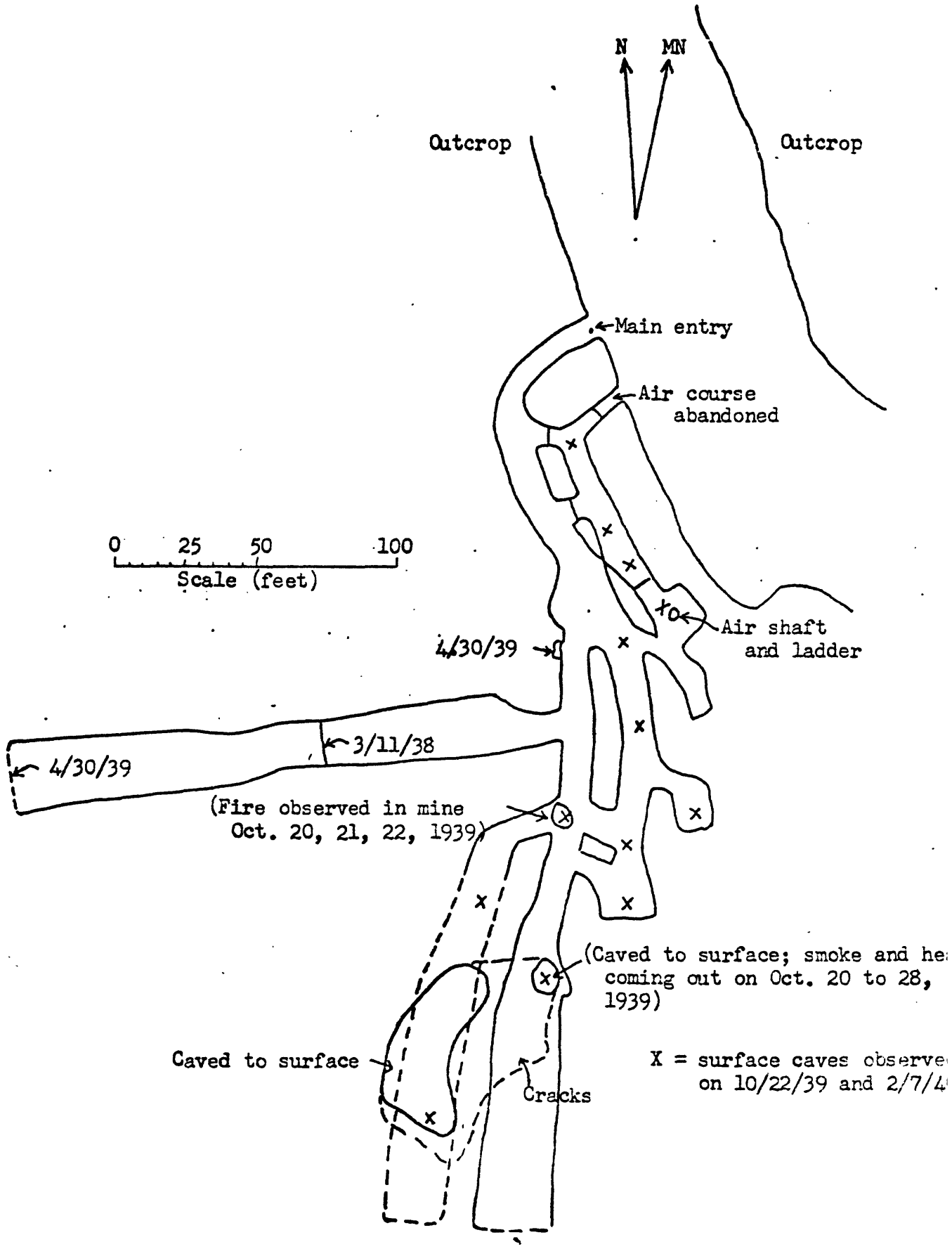
J. J. Bourquin visited the mine again on February 7, 1940, and in his inspection report of February 24 mentioned caving and a small amount of smoke. The caved areas are shown on figure 5, a map showing extensions of the mine as of April 30, 1939.

On June 26, 1941, Bourquin was informed by Deputy State Coal Mine Inspector George H. Smith "that the fire in the abandoned mine had burned through to the surface and that the coal outcrop was burning vigorously" (Bourquin, Inspection Report, July 8, 1941). Bourquin further stated that his examination of June 29, 1941, showed there was "no evidence of active fire * * * at any place in the vicinity of the old mine." Bourquin found that Stander had made two attempts to develop another mine on the property. One of these was about 200 feet northeast of the old mine; a drift was advanced about 25 feet under cover but then abandoned. At another location about 75 feet north of the old mine another drift about 12 feet long was also abandoned.

On September 17, 18, 19, and 22, 1941, F. W. Calhoun inspected the property again (Calhoun, Inspection Report, Sept. 25, 1941) and found that the fire in the old mine "has burned through or around the seals and extended to the outcrop north and south of the haulage portal." Calhoun found that the outcrop fire area extended 105 feet in length; this fire area extended 35 feet north and 70 feet south from the haulage portal. Calhoun described further work to control the fire. On November 4, 1941, J. J. Bourquin and J. D. Turner could find no evidence of fire, but "a small smouldering fire" on the outcrop about 35 feet northwest of the portal was found by Bourquin on January 15, 1943, and another about 75 feet northwest of the portal was found by him on October 30, 1943. No further reports of this mine were found, and the fire presumably ended in 1943.

Production from the Stander mine, for this report, has been determined from the above-cited inspection reports and from records of the State Coal Mine Inspector's office. This production record, which is believed to be relatively complete, is as follows:

Figure 5.- Map of the Stander mine, March 16, 1935, by F. W. Calhoun, extended April 30, 1939, and showing fire and cavings of October, 1939.



Year	Short tons	
1934	86.5	
1935	199.2	
1936	270.0	
1937	384.4	
1938	400.0	
1939	159.0	
1940	41.0	(From outcrop near mine)
Total	1,540.1	

Bates mine: NW¼SW¼ sec. 5, T. 5 S., R. 63 W., Arapahoe County.--To date, the only records found regarding this mine are two inspection reports dated November 16, 1933, and April 2, 1935, by J. J. Bourquin and F. W. Calhoun, respectively. The 1935 report gave no information other than the name.

Bourquin made an inspection of this mine on November 13, 1935, and excerpts from his report are as follows:

> Underground coal mining operations and some stripping operations have been carried on by local ranchmen in the SW¼ sec. 5, T. 5 S., R. 63 W., 6th P.M., during a period of many years and I examined these old workings on November 13, as a means to determine the probable character of coal which may underlie the lands covered by coal permit Denver 043271. The underground workings on the SW¼ of sec. 5 appear to have been abandoned during a period of years. The development was made through a pair of drifts which were driven in the coal bed at the base of a wide face formed by stripping operations. The depth of over-burden at the location where the drifts were begun was approximately fifteen (15) feet. The over-burden consists largely of alternating bands of shale and of coal. These bands vary from a fraction of an inch to eight or ten inches in thickness. The underground workings were so flooded and caved that I was unable to explore them to determine their extent, the character of the coal, and mining conditions. The presence of an "arm-strong" pump and a section of hose near the old portal of the mine served as evidence that somebody recently had attempted to unwater the old workings.
>
> The coal measures at the portal of the old underground workings dip 2°S., 5°E.
>
> Four (4) ranchmen were at work in an open-cut on this property about 100 yards northwest of the old underground workings. The face of the opencut was approximately 18 feet high and the formation in which the cut was being made was similar to that

described as constituting the overburden at the underground workings. Conditions were such that it would be necessary to handle and to sort an enormous amount of material to produce a single ton of coal.

I saw nothing on this property that might be construed as evidence of a coal bed of commercial value.

The mining operations on this property are being conducted by inexperienced men and should be stopped. A hole in the bottom of the open-cut had been charged with 40 per cent dynamite only a few minutes before I arrived on the property. The fuse had been lighted but the charge had failed to detonate. The men had returned to the pit and were endeavoring to drill the shot out. Unaware of what had occurred and of what the men were endeavoring to do, I stood directly over the missed-shot for a period of minutes while talking with the men. When I learned what had happened I endeavored to convince them of their hazardous undertaking. I was successful to the extent that they did not drill directly into the missed-shot but they merely deflected their drill from the collar of the original hole and placed a second charge of dynamite immediately adjacent to the first. Both charges of dynamite were detonated when the fuse of the second shot was ignited.

This mine is in the Strasburg NW quadrangle, of which an open-file report has been issued (Soister, 1972). The mined bed is the A lignite bed of that report, and is the top lignite bed of the lignite zone of the Denver Formation. The mine workings are no longer visible but there is a small cut-bank (the open-cut mentioned by Bourquin, above) on which the upper part of the lignite bed is exposed. Here, I measured the following vertical section of lignite bed A (in inches):

	Thickness (Inches)	
Carbonaceous shale, sandy	20	
Lignite and carbonaceous shale, interbedded, in 1½-3-inch beds	21	
Lignite	11	4.5 feet of lignite in 5.3-ft interval
Carbonaceous shale	1½	
Lignite	5½	
Carbonaceous shale	3	
Lignite	6½	
Carbonaceous clay	½	
Lignite	4½	
Carbonaceous shale	2½	
Lignite	1½	
Carbonaceous shale	2½	
Lignite	25	
Kaolin	1	
Carbonaceous shale (base hidden)	2+	

Unnamed mine: SE¼SE¼NE¼ sec. 6, T. 5 S., R. 63 W., Arapahoe County.--The only reference to this mine is in the brief inspection report dated April 2, 1935, by F. W. Calhoun for coal permit Denver 043271. Following is the bulk of this report:

> However, one of the men working at the Bates mine in the SW¼ of section 5, T. 5 S., R. 63 W., 6th P.M., Colorado, prospected in trespass upon the permit. The trespass is a strip pit located from 185 to 205 feet north and from 0 to 125 feet west of the east ¼ corner of sec. 6, T. 5 S., R. 63 W., 6th P.M., Colorado. The pit was started on east boundary and driven west. The cover varies from 4 feet on east to about 10 feet on west. The pit was started in the edge of a wash and would go under heavier cover south and west up to 200 feet. A considerable portion of the pit was covered with debris which had caved from the vertical side walls.
>
> The coal is very dirty and is badly weathered. It appears to be of no commercial value so far as developed and probably would not be for another 200 feet south or west. No attempt was made to measure a coal section as it could not be measured except in part. The seam appears to be at least 12 feet thick with partings included. The pit is located magnetic N 78°W from the Bates shaft.
>
> The work is said to have been performed during August 1934, by a man living ½ mile south of the pit, who did the work without the knowledge or consent of the permittee. It was stated that no coal was sold therefrom.

The coal bed worked at this pit is also the A lignite bed (Soister, 1972). Apparently very little work was done here, and there is virtually no sign remaining of the small pit described above.

Area of Occurrence

Principal lignite beds of this zone occur in an area about 75 miles long (north-northeast) by 25-35 miles wide (east-west). They extend from the Rocky Mountain Arsenal and Aurora area to south of Calhan and Ramah (map, fig. 1).

Over most of this area the lignite beds are covered by younger bedrock and surficial deposits, but have been penetrated by numerous drill holes. Very few exposures of lignite occur in the northwestern part. More numerous and extensive exposures begin in the western half of T. 4 S., R. 63 W., and continue intermittently in an arcuate area through T. 6 S., R. 62 W., and then to the northwest corner of T. 12 S., R. 61 W., near Calhan. South and southeast of Calhan younger bedrock and 100- to 200-foot-thick surficial deposits lie above the lignite beds. The best and most extensive exposures of lignite beds lie in the valley of West Bijou Creek northward from the vicinity of Fondis.

To the west the lignite zone goes under younger bedrock, with depth increasing to the west. Drill-hole data are very scarce in the deeper part of the Denver Basin, but a few reliable drill-hole logs show some lignite (or subbituminous coal) beds extend west of the 1,000-foot-depth line shown on the large map (fig. 1).

East and northeast of the boundary of the zone shown on the map, there are only a few lenticular lignite beds.

Thickness, Continuity, and Number of Lignite Beds

Thickness of lignite beds, as used in this report, refers to gross thickness and thus includes generally 5-25 percent of clay, sandstone, or carbonaceous shale partings. Therefore, in order to ascertain net lignite thickness of a given bed it would be necessary to deduct some average percentage in this range.

Most lignite beds appear to be in the range of 3-15 feet thick. However, total range in thickness of lignite beds is from a few inches to a maximum known thickness of 54.5 feet. Core hole DX-522e (see log in Appendix II) shows this maximum thickness of 54.5 feet for lignite bed E. However, it should be noted that when the non-coal material is deleted from this log, a net thickness of only 40 feet of lignite remains. Possibly, thinner beds may contain a lower percentage of non-coal partings than thicker beds.

From the available drill-hole data, it seems possible that an axis of greatest lignite deposition, and thus thickest lignite beds, lies from near Watkinsto just east of Kiowa and near Fondis and Calhan.

The large map (fig. 1) indicates only the thickest known bed in each township. Where a water-well log had the greatest thickness in a township, this was discounted to the next lower category; for example, a water-well log in T. 11 S., R. 61 W., shows a 25-foot coal bed, so this is put in the 15-20-foot rather than 20-25-foot category. There may be thicker beds in some townships, particularly those in the western part where drill holes are more widely spaced. Very few coal exploration drill holes completely penetrated the lignite zone; hence, the information in this report is preliminary for most of the area.

Lateral changes in thickness of most individual beds seem to be gradual, not abrupt, and each bed appears to maintain a relatively uniform thickness and character over distances of at least a fraction of a mile to a few miles. Some lignite beds may split into two or more beds and others may grade laterally to mostly or entirely carbonaceous shale. Density logs of three drill holes spaced 1½ miles apart, for a total distance of 3 miles, were found to show that some partings probably no more than a foot or so thick in lignite beds may be correlated for at least this distance. Most lignite beds have a continuity of at least a few miles, and some may extend for 10 miles or more. The E lignite bed extends for more than 18 miles southeast from the vicinity of the Scranton mine.

The number of lignite beds throughout the zone ranges from about 3 to 5 to as many as a dozen or more, although most of these may be thin beds. In the Strasburg NW quadrangle (Soister, 1972), 3 of 5 beds in the upper part of the zone are fairly extensive and thick, whereas the other two are more lenticular. The E lignite bed is the lowest of the five upper beds. Below the E bed the few other lignite beds are thin where penetrated by coal exploration holes and water wells drilled in this quadrangle.

The electric log of Davis Oil Company's Andy 1 test in C NW¼NW¼ sec. 7, T. 5 S., R. 63 W. (Appendix I) is interpreted as indicating that below the E bed, lignite beds which are thin, particularly east of Kiowa Creek, thicken to the west. In this electric log, three lignite beds indicated on the resistivity curves are correlated fairly positively with lignite beds found by coal exploration drill holes about 850 and 2,100 feet away. Very similar resistivity curves lower in the hole indicate three probable lignite beds which were not penetrated by the two coal exploration drill holes but are in the same general stratigraphic interval as the thinner lignite beds east of Kiowa Creek. If my interpretation of this electric log is correct, there is a gross thickness (lignite and partings) of 100 feet in six lignite beds within 600 feet of the surface; 53 feet of this is in definite lignite beds and 47 feet in probable lignite beds. Allowing for the numerous partings, the net lignite thickness would be about 75-90 percent of this gross thickness, or roughly 75-90 feet of lignite.

Quality of the Coal

Quality of the coal has two principal aspects: (1) Number and thickness of non-coal interbeds, and (2) physical character and rank of the pure coal.

The several measured coal sections shown in previous sections of this report and logs of the core holes shown in Appendix II indicate the almost universal occurrence of numerous thin non-coal partings throughout most or all of these lignite beds. In the thinner lignite beds, the lower part of the bed seems to be most free of partings. Thicker lignite beds, at least locally, have a fairly pure lignite a few feet thick at the base; however, especially in the very thick beds, cleaner lignite intervals seem to occur at other levels in some beds.

Partings in the lignite beds are mostly of clay but some are of clayey sandstone, and some descriptions of sections in mines, especially, mention sandstone parting. Although some clay partings, particularly the thicker ones, are not unusual, information so far available, including the present writer's observations, indicate that those a fraction of an inch to a few inches thick are mostly of kaolin. This kaolin is typically grayish orange when fresh but weathers light gray or white so that outcrops of the lignite have typical thin white horizontal bands. Much of the fresh kaolin is in the form of soft fine to coarse books of platy crystals. In drill cores, coarsely crystalline vermicular

(long worm-shaped aggregates) kaolin crystals are conspicuous. Origin of the kaolin apparently was by authigenic alteration of fine-grained arkose thinly interlayered with the carbonaceous material that became lignite; the same lignite beds have some thin layers of fine-grained arkose that appear to be in various states of alteration.

Other interbeds, ranging in thickness from a fraction of an inch to 1 foot or more, are of light- to medium-gray clay and brownish-gray carbonaceous clay and shale. The lignite itself, especially at the base of layers, commonly has clay balls and other inclusions that range mostly from silt size to about 1/4-inch-size particles.

Study of density, radioactivity, and resistivity logs of some coal core holes shows that some partings, perhaps a foot to a few feet thick, in some lignite beds maybe correlated for at least 3 miles. Lateral persistence of even thin partings is a characteristic of these beds.

Physical character and rank of these lignite beds have been touched upon by several previous writers. Eldridge (Emmons, Cross, and Eldridge, 1896, p. 375), in describing coal of the Scranton mine, wrote that it is "a thoroughly representative type of lignite of the plains; its streak is brown; it weathers rapidly and disintegrates completely * * *." This statement is applicable also to the beds throughout the zone in the central and southern part as well as in the old Scranton mine area. The lignite is mostly brownish-black to black, dull to shiny, and it checks and slacks rapidly upon exposure. By this writer's observations, even drill cores of the lignite from as deep as at least 350 feet can crumble under the pressure of being picked up in the hands. Almost all geologists and mining engineers who examined various mines during the 1920's through 1940's described the mined material as lignite. Lack of data in the published literature apparently led others more recently to refer to these beds as subbituminous coal. For example, Landis (1959, p. 161, 162), although citing them as "lignitic" lists them under subbituminous coal.

The quality of the lignite can be judged from analyses of 40 drill core samples, mostly from the E lignite bed in the Watkins-Scranton area. These samples, representing a few inches to a foot or more of thickness, show the following (as-received basis):

Item	Range	Median
Btu	3,285-7,320	6,219
Ash (%)	8-30	17.3
Moisture (%)	22.6-39.2	33.9 ("towel-dried")
Sulfur (%)	0.26-0.55	0.4

The great differences in Btu rating are due mostly to the inclusion of varying amounts of non-coal material (clay partings, blebs, and balls).

Table 2 includes data on the best mine samples and the highest quality core samples. They are representative of the lignites of this zone--Mosby and Purdon mines in the south; Fondis mine in the central part; and DX core holes in the north. These samples, on an as-received basis, show the following (all medians calculated by averaging samples at each site):

Item	Range	Median
Btu	6,060-7,320	6,275
Ash (%)	8.1-17.2	13.9
Sulfur (%)	0.1-0.5	0.4

Moisture content of lignite from the three mines listed (table 2) ranged from 30.9 to 33.5 percent. The report on the two core holes listed indicated 35.8 to 37.2 percent moisture, but this is probably not as representative of the lignites as are the mine samples. The only available specific gravity measurement is the 1.341 for a Scranton mine sample (Eldridge in Emmons, Cross, and Eldridge, 1896, p. 378).

Rank of coal of this zone, or at least of the upper 300 feet, is lignite A (ASTM, 1966) as indicated by calculations made from the data shown in table 2. Thin layers of some beds, particularly in the lower part of the zone, may rank as high as subbituminous C, although no reliable analyses are available that indicate this.

Geology of Thickest Known Lignite Bed

The E lignite bed as designated by Soister (1972) in the Strasburg NW quadrangle (mostly T. 4 S., R. 63 W.) is fairly confidently traced to the thickest bed shown in core holes in the SW¼ T. 3 S., R. 64 W. This tracing is by coal exploration drill holes generally about one-half mile to 1 mile apart and by logs of scattered water wells.

Figures 6 and 7 show the depth to the top and gross thickness of this bed. The northwestern, northern, and eastern edge of the E lignite bed as shown here is the eroded edge of the bed. The southern and western dashed edge shown is the approximate limit of closely spaced drill-hole data, so that characteristics of the bed to the south and southwest are unknown. A major embayment in the edge of the E bed at Watkins is due to the deep paleovalley of Box Elder Creek. Smaller paleovalleys cause other embayments. Lost Creek is one of these. The Lost Creek paleovalley, from about sec. 15, T. 4 S., R. 64 W., northeastward, is believed by the present writer to have represented the original course of Box Elder Creek before stream capture in late Pleistocene time.

Structure of the E lignite bed is broadly and gently undulating. Dips may locally be as much as 2°-3° but a study of the top of the bed in drill holes indicates regional dips of generally 25-50 feet and rarely as much as 100 feet per mile. Regional dip of the bed is generally to the west.

Table 2.--Analyses used to determine coal rank[1]

By ASTM approximation formula:

$$\text{Moist, Mm-free Btu} = \frac{\text{Btu (as-rec'd)}}{100 - (1.1\ \text{Ash} + 0.1\ \text{Sulfur})} \times 100$$

Location	Mine or drill hole	Date sampled	Feet	Ash %	Sulfur %	Btu		Coal rank By formula
						As-rec'd	By formula[1]	
Sec. 18, T. 13 S., R. 61 W.	Mosby mine	1910	4.3	13.9	.3	6,237	7.365	Lignite
Sec. 18, T. 13 S., R. 61 W.	Mosby mine	1911	4.9	12.8	.45	6,720	7,802	Do
Sec. 27, T. 11 S., R. 61 W.	Purdon mine	1910	6.5	13.9	.1	6,060	7,155	Do
Sec. 29, T. 9 S., R. 62 W.	Fondis mine	1928	6.3	14.7	.5	6,700	7,997	Do
Sec. 29, T. 9 S., R. 62 W.	Fondis mine	1923	7.5	17.2	.4	5,860	7,231	Do
Sec. 9, T. 3 S., R. 65 W.	DX-355C[2]	1965	10.7	11.6	.4	6,877	7,886	Do
		1965	2.8	8.1	.4	7,320	8,040	Do
Sec. 29, T. 3 S., R. 64 W.	DX-425C[3]	1965	48.0	15.6	.4	6,098	7,365	Do
		1965	8.0	13.5	.5	6,370	7,485	Do
		1965	8.0	13.0	.4	6,400	7,704	Do
		1965	8.0	16.0	.4	6,140	7,455	Do
		1965	8.0	16.2	.4	6,170	7,511	Do

[1] 8,300 Btu is separation point between lignite A and subbituminous coal.

[2] Includes two samples.

[3] Composite of the four samples shown below and four lower-quality intervals (not shown).

The E lignite bed crops out, in part, on the banks of Kiowa Creek in SW¼ sec. 3, T. 5 S., R. 63 W., just north of the bridge on the east-west county road. Farther north and northwest, only small parts of the bed crop out at a few intermittent locations. Exposures at the surface are inadequate for the study of the thickness and nature of this bed. Hence, the coal exploration drill holes were essential to this study. Scattered water well logs (Soister, 1972) were a very helpful aid in the correlation, but more importantly in the determination of the nature of the beds below the E lignite. They show that the sandstone aquifers most frequently tapped for water in this part of the Denver Basin lie about 200-350 feet below the E lignite. Also, about two to six thinner lignite (or subbituminous coal) beds lie in the interval to about 350 feet below the E lignite.

Depth to the top of the E lignite bed is less than 200 feet over most of the area shown on figure 6. The outer erosional edge (mostly eastern and northern edge) of the bed is mostly a subcrop rather than outcrop, because of the extensive Quaternary deposits. The divide between Kiowa and Box Elder Creeks is low and broad as far south as about 5 miles southeast of Watkins; farther south the divide is several hundred feet high. Below the divide, where it is low and broad, the E bed is covered mostly by thick Quaternary deposits, but is within about 50-200 feet of the surface. Where the divide is several hundred feet high, this almost flat bed is at a corresponding depth below the surface and is overlain predominantly by bedrock.

Gross thickness of the E lignite bed is shown on figure 7. Net thickness of lignite can be determined in core holes. In non-core drill holes, detailed electronic logs perhaps could indicate approximate net thickness; however, because of the numerous very thin partings, it seems unlikely that an accurate net thickness could be determined by these means. Core-hole data should be averaged in order to determine the amount that gross thickness of this and other lignite beds should be discounted in order to arrive at the net lignite thickness in a given area. In the core hole (DX-522C, Appendix II) showing greatest gross thickness of lignite (54.5 feet), eliminating the non-coal partings results in a net lignite thickness of about 40 feet. Thus, the bed here is about 73 percent lignite. Although exact figures cannot be determined, my calculations indicate net figures of about 76 percent and 70 percent lignite in DX-519C and DX-572C (Appendix II).

The E lignite bed apparently is replaced by a channeling sandstone where the zero isopach is shown in the W½ T. 4 S., R. 64 W.; this may have been a penecontemporaneous or younger stream flowing southeastward. Southwest from about secs. 6 through 9, T. 4 S., R. 64 W., the E bed appears to thin abruptly and perhaps to split into two beds. It is difficult to tell which of the two beds, or if both, in the area here, should be designated the E lignite bed. Isopachs shown here are drawn on the basis of only one being this bed; if both are the E lignite, and if both come together farther southwest, thicker isopachs could be indicated here.

There have been insufficient studies made to allow additional paleogeographic implications to be drawn regarding this or any other single lignite bed of this zone.

More than 1½ billion tons of lignite are estimated to be present in the E lignite bed in the area included in figures 6 and 7 (see section on resources).

Utilization of Lignite

Past use of lignite from this zone in the Denver Basin has been mostly for local domestic purposes in areas where better rank coal was not available. Residents of small towns of the region and local ranchers were the principal users. As stated by G. B. Richardson in an unpublished report of 1910, the people in the town of Ramah preferred better coal shipped in by the railroad to that from the Purdon mine. Some or all of this shipped-in coal may have come from mines in the Laramie coal zone near Matheson or at Colorado Springs. Apparently, more lignite was used from the Scranton mine than from all the rest of the zone. This is probably because of the Scranton mine's proximity to Denver, the largest city of the region. A few dozen residents in and near Fondis depended upon the Fondis mine, which was perhaps the next most productive.

Development of the better quality subbituminous coal beds in the Boulder-Weld and Colorado Springs coal fields probably precluded greater development of lignites of the zone. However, physical quality of the lignite is so poor, and considering the manner in which coal has been used in the past, if those fields did not exist it is probable that coal would have been brought to the metropolitan areas from more distant coal fields.

The small mines opened in this lignite zone selectively mined only the cleaner parts of a single coal bed, rejecting the largest part of the bed because of numerous non-coal partings.

One or more of various technological processes presently being developed in private industry and governmental agencies should ultimately be available for application in utilization of these lignites. Gasification perhaps would be the most promising approach because of the very numerous non-coal partings. Gasification *in situ*, if the U.S. Bureau of Mines' current experiment in Wyoming proves successful, is a possibility. Factors favoring gasification *in situ* are that some lignite beds are a few to several hundred feet below the surface, most of the enclosing beds are fine-grained and relatively impermeable, and the numerous non-coal partings would be less detrimental to full use of the lignite by this than by most other methods. Liquefaction or reconstitution are other possible methods. These would be enhanced if some use could be made of the numerous non-coal partings, perhaps mostly kaolin, as a by-product.

These lignite beds probably should not be regarded as normal coal supplies for the usual coal-burning power plant. The lignite is a low-rank coal, is too "dirty" in many parts, has very numerous partings, and slacks rapidly.

Resources

Utilization of the lignite will determine ultimately recoverable resources because some methods will result in non-use of the dirtier parts. Perhaps one-half or more of the total lignite was discarded under the old mining methods and uses. New methods, as mentioned above, could make fuller use of the lignite, thus increasing recoverable resources closer to 100 percent of the lignite present in sufficiently thick and accessible beds.

Except for the area shown in figures 6 and 7, no reserve or resource estimates have been made in my studies. Precise figures of approximate resources are now impossible to determine over much of the area covered by this lignite zone. Water-well logs are too scattered and many are inaccurate as to thickness of lignite beds. Also, very few coal exploration drill holes are deep enough to penetrate most or all of the lignite zone, and, a greater density of drill holes is needed in order to provide meaningful figures.

The most recent reserve estimate of parts of the lignite zone is by Landis (1959, p. 162, 163, 223-225) who lists them under subbituminous coal. These figures should be changed to lignite reserves, and are as follows (in million short tons):

Scranton district - 489
Ramah-Fondis area - 474

SCRANTON DISTRICT

Adams County	
T. 3 S., R. 64 W.	8.76
T. 3 S., R. 65 W.	197.49
T. 3 S., R. 66 W.	10.96
Arapahoe County	
T. 4 S., R. 64 W.	3.29
T. 4 S., R. 65 W.	128.18
T. 4 S., R. 66 W.	140.22

RAMAH-FONDIS AREA

Elbert County	
T. 9 S., R. 61 W.	13.66
T. 9 S., R. 62 W.	137.07
T. 9 S., R. 63 W.	42.80
T. 10 S., R. 61 W.	40.52

RAMAH-FONDIS AREA--Continued

Elbert County--Continued	
T. 10 S., R. 62 W.	56.47
T. 10 S., R. 63 W.	9.11
El Paso County	
T. 11 S., R. 60 W.	58.58
T. 11 S., R. 61 W.	48.00
T. 11 S., R. 62 W.	7.74
T. 12 S., R. 60 W.	22.72
T. 12 S., R. 61 W.	37.61

The present writer has made an estimate (table 3) of measured and indicated reserves of lignite bed E in the area covered by figures 6 and 7. Measured reserves are those for which "the points of observation and measurement are so closely spaced and the thickness and extent are so well defined that the true quantity is judged to be not less than 80 percent of the computed quantity for the bed," (Russell G. Wayland, Chief, Conservation Division, U.S. Geol. Survey, written comm., June 18, 1973). Wayland described indicated reserves as those in which "geologic judgment should lead one to believe that the true quantity is judged to be not less than 50 percent of the computed quantity for the bed." By far the greatest amount here is in the measured category, but no breakdown was attempted for this report. These reserve figures for the E bed were determined from the isopach map (fig. 7), which shows gross thickness, then all figures were reduced to 75 percent to eliminate the non-coal partings and arrive at net lignite figures. This figure is compatible with the 70-, 73-, and 76-percent figures found for the three coal core-hole logs shown in Appendix II (see previous section). A weight of 1,750 short tons per acre-foot was used; this is a standard weight for lignite when more precise figures are not available.

Arriving at realistic total resource figures for the entire lignite zone is very difficult, as explained above (p. 42). Current practice of the U.S. Geological Survey is to disregard coal beds less than 4 feet thick in computing lignite resources, and resource figures used in this report do not include such thinner beds. Beds less than 4 feet thick can no doubt be exploited by some methods, particularly where multiple beds are being worked, and resource figures would be increased accordingly.

In order to make a preliminary attempt to arrive at figures designed to show the approximate order of magnitude of lignite resources, the writer has devised two methods for this lignite zone as shown in table 4. These are the only methods that appear feasible with the data now available. From these calculations of about 17 and 21 billion tons, it seems reasonable to preliminarily assume that minimum lignite resources of this zone, in beds at least 4 feet thick and within 1,000 feet of the surface, are on the order of 20 billion tons.

Table 3.--Estimated reserves of lignite in E bed in area of figure 3
(In millions of short tons, rounded to nearest 10,000 tons)

Adams County	524.74
Arapahoe County	757.31
Total--------	1,282.05

Adams County	
T. 3 S., R. 64 W.	254.36
T. 3 S., R. 65 W.	270.38
Total-------	524.74
Arapahoe County	
T. 4 S., R. 63 W.	175.88
T. 4 S., R. 64 W.	304.24
T. 4 S., R. 65 W.	68.51
T. 5 S., R. 63 W.	186.37
T. 5 S., R. 64 W.	22.31
Total-------	757.31

Table 4.--Two methods of arriving at preliminary estimate of minimum total lignite resources in beds 4 feet or more in thickness and within 1,000 feet of surface, Denver Basin, Colorado

(1) Assume average thickness of 10 feet of lignite over area of lignite zone:

Area (A) = about 1,850 square miles = about 1,184,000 acres
Thickness (T) = 10 feet
Weight of lignite (W) = about 1,750 short tons/acre-foot

A x T x W = 20,720,000,000 short tons
Rounded total = 20.7 billion short tons

(2) Use midpoint of each thickness category of thickest known bed in each township as an average total lignite thickness, then reduce total to 75 percent to eliminate non-coal partings.

Midpoint x townships x 23,040 acres per township = township-feet (TF) of lignite in each category
Sum (S) of TF of all categories = 12,822,000
Weight of lignite (W) = about 1,750 short tons/acre-foot

W x S x 75% = 16,829,000,000 short tons
Rounded total = 16.8 billion short tons

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ADDENDUM

Mines and Production

There are probably several small old mines in the Denver Basin that have not been discussed in this preliminary report. Wesley Corder of Littleton, Colo., recently (April 1974) informed the writer of the following three mines not included in the discussion:

Corder, or Gammon mine, approximately E½SW¼ sec. 25, T. 11 S., R. 61 W.; coal bed reportedly about 14 feet thick.

Daisy mine, approximately E½SW¼ sec. 26, T. 11 S., R. 61 W.

Lamm mine, near center sec. 30, T. 11 S., R. 60 W.

Area of Occurrence

Clinker from the burning of one or more lignite beds is common in the valley of West Bijou Creek. Most of the clinker is found on small knolls and occurs in the following locations:

Secs. 27, 33, and 34, T. 7 S., R. 62 W.
Secs. 10 and 24, T. 8 S., R. 62 W.
Secs. 16, 17, 21, 22, and 28, T. 9 S., R. 62 W.

Quality of the Coal

R. D. Hettinger of the U.S. Geological Survey (oral commun., April 11, 1974) identified kaolinite as the predominant constituent in a sample of one parting from a lignite bed near Ramah. Although kaolinite is commonly attributed to alteration of granitic (thus, arkosic) rocks, a volcanic tuff origin for some of the partings in the lignite cannot be ruled out because 1) some partings are of great lateral extent, and 2) andesitic sediments are common in the Denver Formation. The arkosic sandstones of the Denver Formation commonly contain varying proportions of andesitic materials, and such sandstone, or volcanic tuff, could provide the biotite noted in this sample.

APPENDIX II

Logs of three core holes:

DX-519C: NW corner SW¼ sec. 26, T. 3 S., R. 64 W.

DX-522C: NE corner sec. 30, T. 3 S., R. 64 W.

DX-572C: Near center, west line, sec. 22, T. 3 S., R. 65 W.

FORM 6VB 2/65

DRILL & CORE LOG

HOLE NO. DX-372C

LOG by R.D. Nelson (Geol)
DATE May 3, 1966
PROBED by Century Geophy.

ELEVATION 5566
NORTHING
EASTING

HOLE SIZE 5 7/8" CORE SIZE 5"
DRILLED WITH AIR ☐ WATER ☑
TOTAL DEPTH 170 PROBE DEPTH 170

PROJECT E. Denver Basin
LEASE
LOCATION W 1/4 Corner
SEC. 22 T. 3S R. 65W

REMARKS: Hole is located 25' east of graded sandy road in the middle of the section (using speedometer). It is an offset to DX-372 Box Elder School Quad.

DEPTH	STRIP LOG	THICKNESS	CORED	RECOVERED	% CORE RECOVERY	LITHOLOGY	SAMPLE NUMBER	ANALYSIS
						The is an interpretation of the electric log only, for a detail description of this interval see Core log.		
130						Clay, silty, with sandstone interbed; probably lignitic towards base.		
139		39.0				lignite, with Clay interbeds as shown.		
169						Clay, with thin lignite at the		

HOLE NO. DX-372C

Electric Log

FORM RVB 3/83

DRILL & CORE LOG

HOLE NO. DX-514C

LOG By P.M. Veterine (Geol)

DATE

PROBED By

ELEVATION

NORTHING

EASTING

HOLE SIZE CORE SIZE

DRILLED WITH AIR ☐ WATER ☐

TOTAL DEPTH PROBE DEPTH

PROJECT

LEASE

LOCATION

SEC. , T. , R.

REMARKS:

DEPTH	STRIP LOG	THICKNESS	CORED	RECOVERED	% CORE RECOVERY	LITHOLOGY	SAMPLE NUMBER	ANALYSIS
						Run #4 95.5 - 98.5 (3.0') 3.0' recovered (100%)		
10						95.5 - 95.85: Lignite, good quality, with quite a bit of disseminated Coaliite, (grades to Clay below).		
20						95.85 - 96.92: Clay, grey, with green cast, lignitic - especially at top, waxy.		
30						96.92 - 98.05: Clay, grey, waxy, lignitic becomes highly lignitic between 97.40 - 98.05.		
40						98.05 - 98.50: Clay, grey, waxy.		
50								
60								
70								
80								
90								
100								
110								
120								
130								
140								
150								
160								
170								
180								
190								
200								
210								

(4)

FORM BVS 3/63

DRILL & CORE LOG

HOLE NO. DX5196

LOG By R.M Vetorino (Geol)
DATE
PROBED By

ELEVATION
NORTHING
EASTING

HOLE SIZE ____ CORE SIZE ____
DRILLED WITH ____ AIR ☐ WATER ☐
TOTAL DEPTH ____ PROBE DEPTH ____

PROJECT
LEASE
LOCATION
SEC. ____, T. ____, R. ____

DEPTH	STRIP LOG	THICKNESS	CORED	RECOVERED	% CORE RECOVERY

REMARKS:

LITHOLOGY	SAMPLE NUMBER	ANALYSIS

83.90 - 84.02: Kaolinite, tan, crystalline, waxy.
84.02 - 85.40: Lignite, with Kaolinite bands at: 84.14 - 84.16, 84.18 - 84.20, 84.25 - 84.31, 84.73 - 84.76.
85.40 - 85.44: Kaolinite, tan, crystalline, waxy.
85.44 - 85.82: Lignite, with considerable Kaolinite disseminated throughout.
85.82 - 85.87: Kaolinite, tan, crystalline, pearly.
85.87 - 86.23: Lignite, slightly Kaolinitic.
86.23 - 86.64: Kaolinite, with lignite stringers especially at 86.36 - 86.45.
86.64 - 87.3 Lignite, good quality, with Kaolinite at: 86.78 - 86.81, & 87.10 - 87.14.
End of Run #2

Run #3: 87.5 - 95.5 (8.0'); 8.0 recovered (100%)
87.5 - 90.24: Lignite, black, hard, good quality, with Kaolinite beds at: 87.9 - 87.84, 88.10 - 88.26, 88.92 - 87.94, & 89.44; leases at 89.81 - 89.89
90.24 - 90.52: Kaolinite, tan, crystalline, waxy, interbedded with Lignite.
90.52 - 90.92: Lignite with occasional Kaolinite band.
90.92 - 91.03: Kaolinite, crystalline & pearly.
91.03 - 92.01: Lignite, good quality, with bands of Kaolinite.
92.01 - 92.32: Interbedded lignite with lignitic Kaolinite.
92.32 - 92.78: Kaolinite, crystalline, & pearly, with lignite partings.
92.78 - 93.55: Lignite with Kaolinite beds at: 92.91 - 92.93, 93.08 - 93.11, 93.25 - 93.27, 93.32 - 93.34.
93.55 - 93.72: Interbedded Kaolinite & Lignite.
93.72 - 93.98: Lignite with lens of Kaolinite at 93.85 - 93.87 (Kaolinitic otherwise).
93.98 - 94.47: Lignitic Kaolinite, tan to light grey, crystalline in part, possibly contains some grey clay material.
94.47 - 94.60: Interbedded Lignite & Kaolinite.
94.60 - 95.52 Lignite with lens of Kaolinite at 94.85 - 94.87.

End of Run #3

DX 5196

(5)

FORM 8V8 3/65

DRILL & CORE LOG

HOLE NO. DX-519

LOG By L.M. Veterino (Geol)
DATE Dec 10, 1965
PROBED By Century Geophy

ELEVATION 5534
NORTHING
EASTING

HOLE SIZE 4 3/4 CORE SIZE
DRILLED WITH AIR ☐ WATER ☐
TOTAL DEPTH 123 PROBE DEPTH 123

PROJECT E. Denver Basin
LEASE
LOCATION: NW cor. SW¼
SEC. 26 , 35 , 64W

REMARKS: Hole is located 25' east of DX-518, approximately 95' ea
& 1225 north of SW Corner of Section Monarch Quadrangle

DEPTH	STRIP LOG	THICKNESS	CORED RECOVERED	% CORE RECOVERY	LITHOLOGY	SAMPLE NUMBER	ANALYSIS
					This is an interpretation of the electric log only and is made for a comparison with the actual core log.		
70					Clay very silty		
					Clay slightly silty		
		28.5			Lignite with clay beds as follows: 76-76.5, 78.5-79, 80.5-81, 83.5-84, 87-88, 93-93.5, 94.5-95.		
96.5					Other minor clay intervals are suggested on resistance log, and on gamma log.		
					Clay		
					clayey Siltstone		

(C)

FORM RVB 3/65

DRILL & CORE LOG

HOLE NO. DX519C

LOG By R.M. Veloziano (Geol)
DATE Dec 10, 1965
PROBED By Century Geophy.

ELEVATION 5534
NORTHING
EASTING

HOLE SIZE 4¾" CORE SIZE
DRILLED WITH AIR ☐ WATER ☑
TOTAL DEPTH 123 PROBE DEPTH 123

PROJECT E. Beaver Basin
LEASE
LOCATION SW Corner
SEC. 26 T. 3S R. 64W

REMARKS: Hole is located 25 east of DX 518, approximately 95' east & 1225 north of SW Corner of Section. Manila Quadrangle.

DEPTH	STRIP LOG	THICKNESS	CORED	RECOVERED	% CORE RECOVERY	LITHOLOGY	SAMPLE NUMBER	ANALYSIS
						0' to 70.5' was not cored in this hole. See DX 518 for description of this interval.		
70						Run #1: 70.5 - 78.5 (8.0'); 6.4 recovered (80%).		
						70.5 - 71.33: Lignite, black, hard, shiny, angular, good quality, but badly broken up.		
72						71.33 - 71.43: Kaolinite, tan, crystalline, pearly with lignite interbed.		
74					80%	71.43 - 73.75: Lignite, with Kaolinite bands at 71.59 - 71.64, 71.77 - 71.83, 72.18 - 72.24; other minor Kaolinite lenses. Core badly broken up 72.70 - 73.35.		
76						73.75 - 73.88: Kaolinite, tan, pearly, crystalline with Lignite lenses		
78						73.88 - 74.64: Lignite, good quality, with numerous Kaolinitic bands.		
80						74.64 - 75.03: Lignite, good quality, with thin Kaolinite bands.		
82					95%	75.03 - 75.32: Interbedded Kaolinite & Lignite.		
84						75.32 - 76.32: Lignite, good quality, occasional Kaolinite bands.		
86						76.32 - 76.9 Kaolinite & Lignite interbedded (ea. 40)		
88						End of Run #1		
						Run #2: 78.5 - 87.5 (9.0'); 8.8' recovered (98%)		
90						78.5 - 78.89: Lignite, good quality, hard.		
92					100%	78.89 - 79.06: Kaolinite, tan, crystalline, interbedded with Lignite.		
94						79.06 - 79.82: Lignite, hard, good quality, with thin partings of Kaolinite.		
96						79.82 - 79.96: Kaolinite, tan, crystalline, worny.		
98					100%	79.96 - 80.11: Lignite, good quality.		
						80.11 - 80.18: Kaolinite, as above, but poorly in part.		
100						80.18 - 82.69: Lignite, good quality with Kaolinite beds or bands at: 80.43 - 80.48, 80.48 - 80.76, 80.96 - 80.97, 81.03 - 81.07, 81.42 - 81.45, 81.64 - 81.68, 81.88 - 81.96, & 82.55 - 82.61.		
120						82.69 - 83.82: Kaolinite, tan, crystalline (worny in part), pearly in part, with lignite partings.		
140						82.82 - 83.08: Lignite, good quality.		
160						83.08 - 83.36: Kaolinite, tan, mostly crystalline but some appears amorphous.		
180						83.36 - 83.90: Lignite, good quality, with Kaolinite		
200								
220								

DRM RVB 3/65

(7) DRILL RECORD LOG

HOLE NO. DX522C

LOG By L. Veterma (Geol)

DATE

PROSED By

ELEVATION

NORTHING

EASTING

HOLE SIZE CORE SIZE

DRILLED WITH AIR ☐ WATER ☐

TOTAL DEPTH PROBE DEPTH

PROJECT

LEASE

LOCATION

SEC. ,T. ,R.

REMARKS:

DEPTH	STRIP LOG	THICKNESS	CORED	RECOVERED	% CORE RECOVERY	LITHOLOGY	SAMPLE NUMBER	ANALYSIS
						113.2 - 114 : Lignite, good quality, clayey at top.		
10						114.0 - 114.35 : Clay, grey.		
20						114.35 - 114.65 : Clay, light grey, silty, lignite in part.		
30						114.65 - 115.0 : Clay, as above, but with green cast.		
40								
50								
60								
70								
80								
90								
100								
110								
120								
130								
140								
150								
160								
170								
180								
190								
200								
210								

HOLE NO. DX522C

Core Log

(8)

FORM BVB 3/65

DRILL & CORE LOG

HOLE NO. DX 522 C

LOG By L.M Veteanu (Geol)
DATE
PROBED By

ELEVATION
NORTHING
EASTING

HOLE SIZE ____ CORE SIZE ____
DRILLED WITH ____ AIR ☐ WATER ☐
TOTAL DEPTH ____ PROBE DEPTH ____

PROJECT
LEASE
LOCATION
SEC. ____, T. ____, R. ____

REMARKS:

DEPTH	STRIP LOG	THICKNESS	CORED RECOVERED	% CORE RECOVERY	LITHOLOGY	SAMPLE NUMBER	ANALYSIS
					101.47 - 102.72 : Lignite, with numerous thin Kaolinitic bands & one white Kaolinite bed at 102.18 - 102.32.		
					102.72 - 102.88 : Lignitic Kaolinite.		
					102.88 - 103.08 : dirty Lignite, very kaolinitic.		
					103.08 - 103.17 : Kaolinite, tan, crystalline, greasy in part.		
					103.17 - 103.70 : Lignite, good quality.		
					103.70 - 104.49 Kaolinite with two Lignite beds at 104.0 - 104.11 & 104.18 - 104.32.		
					104.49 - 105.79 : Lignite, good quality, very Kaolinitic 104.62 - 104.74 ; includes Kaolinite beds at 104.88 - 104.95, 105.40 - 105.50.		
					105.79 - 105.95 Lignitic Clay grey soft		
					105.95 - 106.95 : Lignite, with Kaolinite lenses at 106.02 - 106.05, 106.38 - 106.40 106.66 - 106.92.		
					106.95 - 107.38 : dirty Lignite, grey, clayey		
					107.38 - 107.68 Lignite.		
					107.68 - 108.32 : Clay, grey, sub waxy, lignitic.		
					108.32 - 108.50 : Lignite, good quality, broken up.		
					End of Run # 7		
					Run # 8 ; 108.5 - 112 (3.5') ; 3.5' recovered (100%)		
					108.5 - 108.77 : highly Kaolinitic Lignite.		
					108.77 - 110.58 : Lignite, good quality, with Kaolinite bands ; prominent ones at 109.24 - 109.32 109.38 - 109.43, 109.59 - 109.64, 110.15 - 110.20, 110.23 - 110.25.		
					110.57 - 110.70 : kaolinitic Lignite.		
					110.70 - 111.30 : Lignite, good quality, kaolinitic		
					111.30 - 111.4 Kaolinite		
					111.4 - 113.0 kaolinitic Lignite with beds of Kaolinite at 111.62 - 111.70, 111.79 - 111.83.		
					End of Run # 8		
					Run # 9 ; 112 - 116 (4.0') ; 3.4' recovered (85%)		
					113.0 - 113.11 : Lignite, good quality.		
					113.18 - 113.13 : kaolinitic Lignite. (good at 113.44 - 113.52)		
					113.13 - 113.38 Lignite good quality.		
					113.38 - 113.82 Lignitic Kaolinite (appears to		

(9)

FORM BVB 3/65

DRILL & CORE LOG

HOLE NO. DX522C

LOG By L.M. Veterino (Geol.)
DATE
PROBED By

ELEVATION
NORTHING
EASTING

HOLE SIZE CORE SIZE
DRILLED WITH AIR ☐ WATER ☐
TOTAL DEPTH PROBE DEPTH

PROJECT
LEASE
LOCATION
SEC. ,T. ,R.

REMARKS:

DEPTH	STRIP LOG	THICKNESS	CORED RECOVERED	% CORE RECOVERY	LITHOLOGY	SAMPLE NUMBER	ANALYSIS
					90.90 - 91.63: Lignite with kaolinite leases at 91.12 - 91.21, 91.32 - 91.34.		
10					91.63 - 91.8: Lignite, dirty with Kaolinite.		
20					End of Run # 5		
					Run # 6: 92.0 - 99.8 (7.8'); 7.5 recovered (96%)		
30					92.00 - 92.28: Lignite, dirty with Kaolinite.		
40					92.28 - 92.84: Lignite good quality with Kaolinite beds at 92.54 - 92.56, 92.72 - 92.75.		
50					92.84 - 93.07 Kaolinite lignitic with lignite bed at 92.87 - 92.90		
60					93.07 - 94.4: Lignite, good quality, with Kaolinite beds at 93.19 - 93.24, 93.72 - 93.74; rarely veined 94.0 - 94.12.		
70					94.4 - 94.96 Interbedded Kaolinite & lignite.		
80					94.96 - 95.55: Lignite, good quality, but broken up, very kaolinitic 95.22 - 95.45, Kaolinite bed 95.44 - 95.46		
90					95.55 - 97.20: Lignite, good quality, kaolinitic, with Kaolinite beds at 95.71 - 95.76, 96.53 - 96.64, 96.87 - 96.96.		
100					97.20 - 97.65: Lignite, good quality, with Kaolinite leases; badly broken up.		
110					97.65 - 97.93: Lignite, good quality, with Kaolinite bed at 97.76 - 97.81.		
120					97.93 - 98.15: Lignitic Clay, grey, fairly soft		
130					98.15 - 98.85: Lignite with Kaolinite leases at 98.42 - 98.44, 98.46 - 98.48, 98.65 - 98.71.		
140					98.85 - 99.35: Lignite, with some soft Kaolinite interbeds but badly broken up. (depths?)		
150					99.35 - 99.50: Lignite, good quality.		
160					End of Run # 6.		
					Run # 7: 99.8 - 108.5 (8.7'); 8.7' recovered (100%).		
170					99.80 - 99.96: Kaolinite, crystalline, waxy.		
180					99.96 - 100.27: Lignite, good quality.		
					100.27 - 100.62: Kaolinite, amorphous.		
190					100.62 - 101.13: Lignite, good quality, dirty at 101.05 - 101.13.		
200					101.13 - 101.25: Kaolinite, soft, waxy, sooty.		
					101.25 - 101.47: Interbedded Lignite (60%) & Kaolinite (40%)		

(19)

FORM EVS 3/65

DRILL & CORE LOG

HOLE NO. DX522C

LOG By R.M. Veloria (Acad)
DATE
PROBED By

ELEVATION
NORTHING
EASTING

HOLE SIZE ____ CORE SIZE ____
DRILLED WITH ____ AIR ☐ WATER ☐
TOTAL DEPTH ____ PROBE DEPTH ____

PROJECT
LEASE
LOCATION
SEC. ____, T ____, R. ____

REMARKS:

DEPTH	STRIP LOG	THICKNESS	CORED	RECOVERED	% CORE RECOVERY	LITHOLOGY	SAMPLE NUMBER	ANALYSIS
92.0						75.72 - 75.80 : Kaolinite, tan, crystalline & amorphous.		
						75.8 - 76.05 : kaolinitic lignite.		
						76.05 - 77.40 : Lignite, good quality, with numerous leases of Kaolinite.		
						77.4 - 77.62 : Lignite Kaolinite		
					96%	77.62 - 78.23 : Lignite, good quality, with leases of grey Clay especially at bottom.		
						78.23 - 78.53 : Clay, grey with lignite partings.		
						78.4 - 78.82 : Lignite, appears dirty (with Clay).		
						78.83 - 79.45 : Lignite, good quality, with occasional grey Clay leases.		
						79.45 - 79.50 : Kaolinite, tan, crystalline.		
						End of Run #3		
					100%	Run #4: 79.5 to 84 (4.5'); 4.5' recovered (100%)		
						79.5 - 80.55 : Lignite, Kaolinitic, with Kaolinite band at 79.87 - 79.90.		
						80.55 - 80.73 : Lignite, but highly kaolinitic		
						80.73 - 80.87 : Kaolinite Lignitic.		
						80.87 - 81.22 : Lignite, appears dirty with grey Clay.		
					100%	81.22 - 84.00 : Lignite, good quality, with occasional Kaolinite lens or band, the most prominent is at 81.93 - 81.95. Core from 82.58 - 84.0 is badly broken up.		
						End of Run #4		
116.0	Coal					Run #5: 84.0 - 92.0 (8.0'): 7.8 recovered (98%)		
						84.0 - 85.05 : Lignite, good quality, kaolinitic in part with Kaolinite beds at 84.06 - 84.18, 84.52 - 84.64.		
						85.05 - 86.68 : Lignite, good quality, with several sheets & fairly thin grey Clay leases (possibly Kaolinite).		
						86.68 - 86.77 : Kaolinite, tan, crystalline, pasty.		
						86.77 - 88.23 : Lignite good quality kaolinitic with Kaolinite leases at 87.16 - 87.21, 87.42 - 87.46, 87.54 - 87.57, 87.73 - 87.75, 87.90 - 87.92, 88.06 - 88.10, 88.21 - 88.23.		
						88.23 - 90.78 : Lignite, good quality, occasionally kaolinitic with numerous grey leases that appear to be clayey.		
						90.78 - 90.90 : Kaolinite, tan, crystalline		

(11)

FORM BVD 3/65

DRILL & CORE LOG

HOLE NO. DX 622 C

LOG By L M Vetorino (Geol)
DATE Dec 14, 1965
PROBED By Century Geophy.

ELEVATION 5502
NORTHING
EASTING

HOLE SIZE 4 3/4" CORE SIZE
DRILLED WITH AIR ☐ WATER ☑
TOTAL DEPTH 125 PROBE DEPTH 125

PROJECT E. Denver Basin
LEASE
LOCATION SE Corner
SEC. 19, T. 3 S, R. 64 W

REMARKS: Hole is located 25' west & 6' south of DX 80; 6' south of fence marking north edge of county right-of-way. Manila Quadrangle

DEPTH	STRIP LOG	THICKNESS	CORED	RECOVERED	% CORE RECOVERY	LITHOLOGY	SAMPLE NUMBER	ANALYSIS
						0' to 56.5' was not cored in this hole. See DX 80 for description of this interval.		
56.5						Run #1: 56.5 - 63.5 (7.0'); 3.8' recovered (54%)		
						56.5 - 60.2: Clay, grey, with rusty stain, waxy, slightly silty, moderately firm.		
60.2					54%	60.2 - 60.3: Kaolinite, tan, crystalline, worm-y. (The remaining portion of cored interval is believed to be soft lignite that washed away)		
60.3						End of Run #1		
63.5						Run #2: 63.5 - 71.5 (8.0'); 4.8' recovered (60%)		
63.5						63.5 - 63.82: Lignite, very kaolinitic, fairly soft.		
63.82						63.82 - 64.15: Kaolinite, tan, crystalline, waxy.		
64.15						64.15 - 65.01: Lignite, hard, good quality, but badly broken up (Gently as result of vertical fractures)		
65.01					60%	65.01 - 65.15: Lignitic Kaolinite.		
65.15						65.15 - 65.93: Lignite, broken up.		
65.93						65.93 - 66.35: Lignitic Kaolinite (or dirty lignite)		
66.35						66.35 - 66.43: Kaolinite.		
66.43						66.43 - 66.90: Lignite, good quality with Kaolinite bands at: 66.60 - 66.62, 66.65 - 66.68.		
66.90					100%	66.90 - 68.10: Interbedded dirty lignite & Kaolinite.		
68.10						68.10 - 68.30: Kaolinitic lignite, (Portion missing is probably soft lignite that washed away).		
68.30						End of Run #2		
71.5						Run #3: 71.5 - 79.5 (8.0'); 8.0' recovered (100%)		
71.5						71.5 - 71.87: Kaolinitic lignite.		
71.87						71.87 - 72.22 highly kaolinitic lignite with Kaolinite lenses.		
72.22						72.22 - 72.37: Kaolinite, crystalline, slightly gritty.		
72.37						72.37 - 72.45: Lignite, good quality.		
72.45					98%	72.45 - 73.72: Kaolinite lignitic at Top		
73.72						73.72 - 74.15: dirty lignite, very kaolinitic. (Good lignite band at 83.48 - 83.53.)		
74.15						74.15 - 74.22: lignite, fairly good quality.		
74.22						74.22 - 74.44: Kaolinite, tan, crystalline, with lignite partings.		
74.44						74.44 - 74.49: lignite, kaolinitic		
74.49						74.49 - 74.98: Lignitic Kaolinite.		
74.98						74.98 - 75.72: Lignite good quality with occasional		

Continued on Second Sheet

(12) DRILL & CORE LOG

HOLE NO. DX 52 2C

L. M. Veterino (Geol.)
Dec. 14, 1965
LOGGED BY Century Geophys.

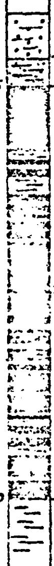
ELEVATION 5502
NORTHING
EASTING

HOLE SIZE 13/4 CORE SIZE
DRILLED WITH AIR ☐ WATER ☑
TOTAL DEPTH 125 PROBE DEPTH 125

PROJECT E. Beaver Basin
LEASE
LOCATION NE Corner
SEC. 30 T. 35 R. 64 W

REMARKS: Hole is located 25' west & 6' south of DX 80, 6' south of fence marking north edge of County right-of-way. Meadow Quadrangle

DEPTH	STRIP LOG	THICKNESS	CORED	RECOVERED	% CORE RECOVERY	LITHOLOGY	SAMPLE NUMBER	ANALYSIS
						This is an interpretation of the electric log only, and was made for a comparison with the actual core log		
						clayey Sandstone		
						silty Clay		
60.5		54.5'				Lignite with major clay beds as follows: 69-70, 71-71.5, 72-75, 76-76.5, 77.5-78, 78.5-79, 81-81.5, 88-88.5, 92.5-93, 93.5-94, 94.5-95.5, 97.5-98, 98.5-99, 101-101.5, 103.5-104, 104.5-105.5, 106.5-107, 108-109.5, 112-113. Total major clay 14'. Other minor clay intervals are suggested on resistance log, and on gamma log.		
115.0						Clay		



HOLE NO. DX 52 2C
Electric Log Interpretation

FORM RVB 3/65

(13)

DRILL & CORE LOG

HOLE NO. 2K59C

LOG By E.M. Victoriano (Geol.)

DATE

PROBED By

ELEVATION

NORTHING

EASTING

HOLE SIZE ____ CORE SIZE ____

DRILLED WITH ____ AIR ☐ WATER ☐

TOTAL DEPTH 170 PROBE DEPTH 170

PROJECT

LEASE

LOCATION

SEC. ____, T. ____, R. ____

REMARKS:

DEPTH	STRIP LOG	THICKNESS	CORED	RECOVERED	% CORE RECOVERY	LITHOLOGY	SAMPLE NUMBER	ANALYSIS
						To assembly		
10						158.12 - 158.9: Clay, light grey, waxy, but fica.		
20						158.9 - 159.1: Clay, dark grey, lipolitic.		
						159.1 - 159.3: Clay, with crystals & pods of Kaolinite.		
30						159.3 - 159.4: Clay, grey, waxy.		
40								
50								
60								
70								
80								
90								
100								
110								
120								
130								
140								
150								
160								
170								
180								
190								
200								
210								

DRILL & CORE LOG

HOLE NO. DK573C

(14)

LOG BY R.M. Peterson (Geol.)
DATE
PROBED BY

ELEVATION
NORTHING
EASTING

HOLE SIZE / CORE SIZE
DRILLED WITH AIR ☐ WATER ☐
TOTAL DEPTH / PROBE DEPTH

PROJECT
LEASE
LOCATION
SEC. , T. , R.

REMARKS:

DEPTH	STRIP LOG	THICKNESS	CORED	RECOVERED	% CORE RECOVERY	LITHOLOGY	SAMPLE NUMBER	ANALYSIS
						to 144.0 then very broken up.		
10								
						Core #4, 146.7 - 153.0 (6.3'), Recovered 6.3', 100%.		
20						146.7 - 148.43: Lignite, good quality with Kaolinite lenses at 147.12 - 147.25, 147.85 - 147.93 numerous thin partings kaolinite from 148.12 - 148.43		
40						148.43 - 149.56: Interbedded Lignite & Kaolinite numerous veils.		
50						149.56 - 150.96: Lignite, good quality, badly broken up.		
						150.96 - 151.48: Kaolinite with Lignite band at 151.37 - 151.42.		
						151.48 - 151.64: Lignite & Kaolinite interbedded.		
70						151.64 - 152.15: Lignite, good quality.		
						152.15 - 152.25: Interbedded Lignite & Kaolinite		
80						152.25 - 152.6: Lignite, kaolinitic, with thin Kaolinite partings.		
90						152.6 - 153.0: Clay & Lignite badly broken & mixed; Clay is grey.		
100								
						Core #5, 153.0 - 155.4 (2.4'), Recovered 1.7', 71%.		
110						Lost bottom of core down hole as barrel was pulled out of hole.		
						153.0 - 153.1: Clay, grey to tan, kaolinitic.		
						153.1 - 153.48: Lignite, kaolinitic.		
130						153.48 - 153.61: Kaolinite		
						153.61 - 153.86: Lignite, kaolinitic.		
140						153.86 - 153.96: Kaolinite, tan, crystalline.		
						153.96 - 154.07: Lignite, kaolinitic.		
150						154.07 - 154.22: Kaolinite		
						154.22 - 154.7: Interbedded Lignite & Kaolinite.		
160						154.7 - 155.4: Lost		
170						Core #6, 155.4 - 159.4 (4.0'), Recovered 4.0, 100%.		
						155.4 - 155.65: Lignite with Kaolinite partings		
180						155.65 - 155.97: Lignite, good quality, lenses of Kaolinite 155.88 - 155.92.		
190						155.97 - 156.11: Kaolinite, tan, crystalline.		
						156.11 - 156.33: Lignite with Kaolinite partings		
200						156.33 - 156.43: Kaolinite, tan, crystalline.		
						156.43 - 157.25: Lignite, good quality, becomes clayey 157.05.		
						157.25 - 158.12: Clay, grey, lignitic, fissil, soft		

HOLE NO. DK573C

Core Log

FORM EVS 3/65

(15) DRILL & CORE LOG

HOLE NO. DX572C

LOG By L.M. Villarino (Geol)
DATE May 3, 1966
PROBED By Century Geophy

ELEVATION 5566
NORTHING
EASTING

HOLE SIZE 5 1/8" CORE SIZE 5"
DRILLED WITH ___ AIR ☐ WATER ☑
TOTAL DEPTH 170 PROBE DEPTH 170

PROJECT E. Denver Basin
LEASE
LOCATION W/4 Corner
SEC. 22, T. 35, R. 65W

REMARKS: See Electric Log Interpretation

DEPTH	STRIP LOG	THICKNESS	CORED	RECOVERED	% CORE RECOVERY	LITHOLOGY	SAMPLE NUMBER	ANALYSIS
						For a description of the interval in the upper part of this hole see DX339		
						Core #1, 129.5 - 135.4 (5.9') Recovered 5.9, 100%.		
						129.5 - 130.38: Clay, grey waxy		
						130.38 - 132.95: Lignite, black, hard, fairly shiny, blocky & angular, occasionally kaolinitic, mostly broken up.		
					100%	132.95 - 133.4: Kaolinite, tan, mostly peachy, crystalline, with occasionally thin leases of lignite.		
						133.4 - 134.5: Lignite good quality		
						134.5 - 134.73: Lignite, highly kaolinitic.		
						134.73 - 134.93: Kaolinite & lignite interbedded		
						134.93 - 135.08: Kaolinite, lignitic.		
					100%	135.08 - 135.4: Clay, grey, kaolinitic.		
						Core #2, 135.4 - 141.0 (5.6') Recovered 5.6', 100%.		
						135.4 - 135.54: Kaolinite, crystalline, peachy, lignitic.		
						135.54 - 136.43: Lignite, good quality, with Kaolinite leases at 135.52 - 135.68, 136.13 - 136.17.		
					100%	136.43 - 136.49: Kaolinite, crystalline.		
						136.49 - 136.65: Lignite, kaolinitic.		
						136.65 - 136.80: Kaolinite, tan, waxy, lignitic.		
						136.80 - 136.92: Lignite, good quality.		
						136.92 - 137.12: Kaolinite, pure.		
					100%	137.12 - 137.49: Lignite, good quality.		
						137.49 - 137.79: Kaolinite, waxy, crystalline, lignitic, with lignite band at 137.74 - 137.76.		
						137.79 - 137.87: Lignite, as above.		
						137.87 - 138.4: Kaolinite, very lignitic.		
						138.4 - 140.0: Lignite, good quality, mostly broken up, with Kaolinite band at 138.51 - 138.64 Lignite is kaolinitic 138.95 - 139.13.		
					100%	140.0 - 140.75: Lignite, good quality, but broken up, moderately kaolinitic.		
						140.75 - 140.94: Interbedded Kaolinite & Lignite.		
						140.94 - 141.0: Kaolinite tan crystalline lignitic		
						Core #3, 141.0 - 146.7, (5.7') Recovered 5.7' 100%.		
						141.0 - 141.25: Kaolinite, tan, crystalline, lignitic with occasional lignite partings.		
						141.25 - 146.7: Lignite, good quality, only occasionally kaolinitic, moderately broken up down		

HOLE NO. DX572C
Core Log