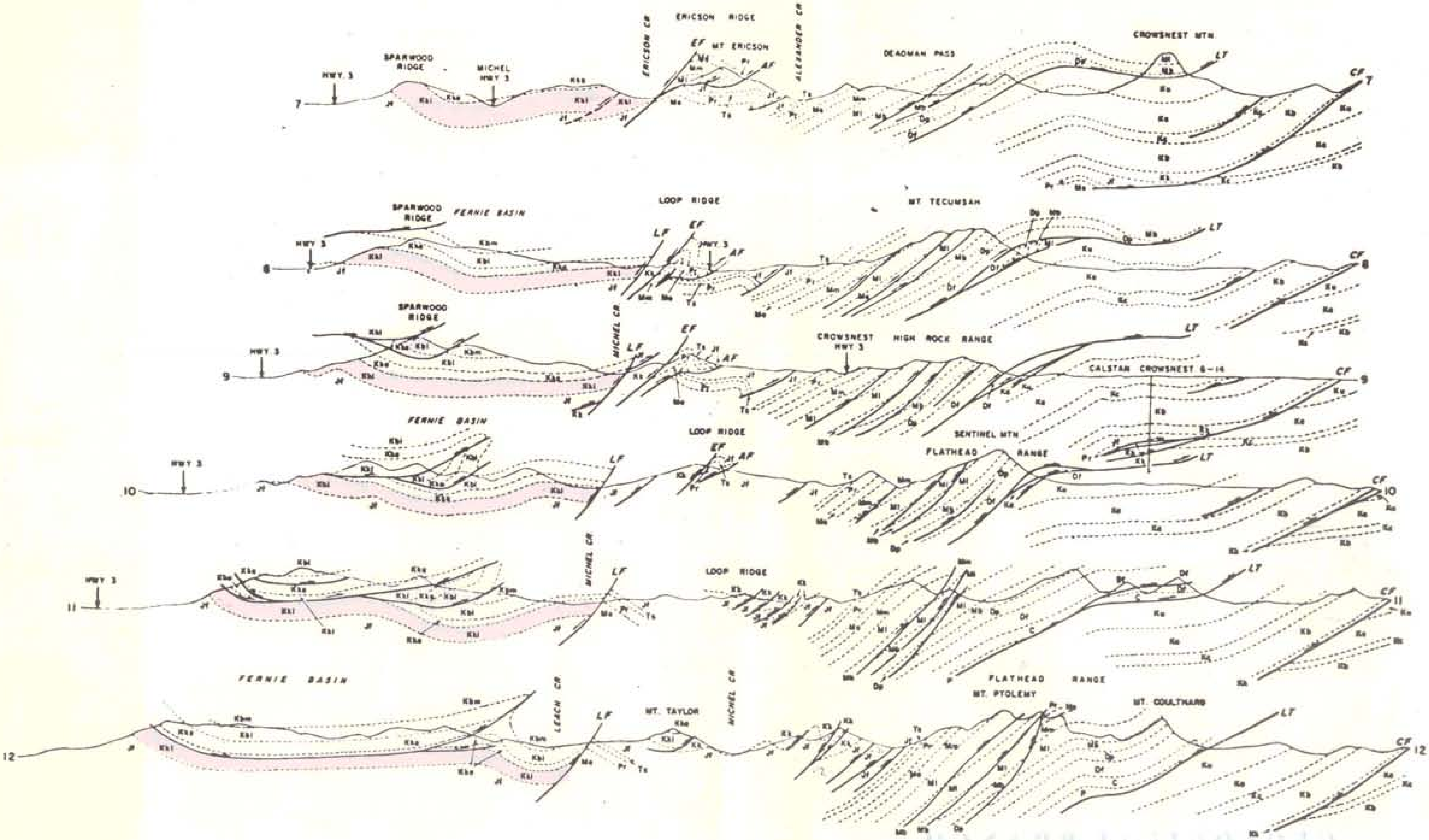


Fig. 1.—Geologic structure of the central part of the Rocky Mountains in the vicinity of Crowsnest Pass

SCALE 1" = 2 MILES

00096

GROSSMAN PEAK
Looking at footwall, Location A

GROSSMAN PEAK
Looking southeast near Location A

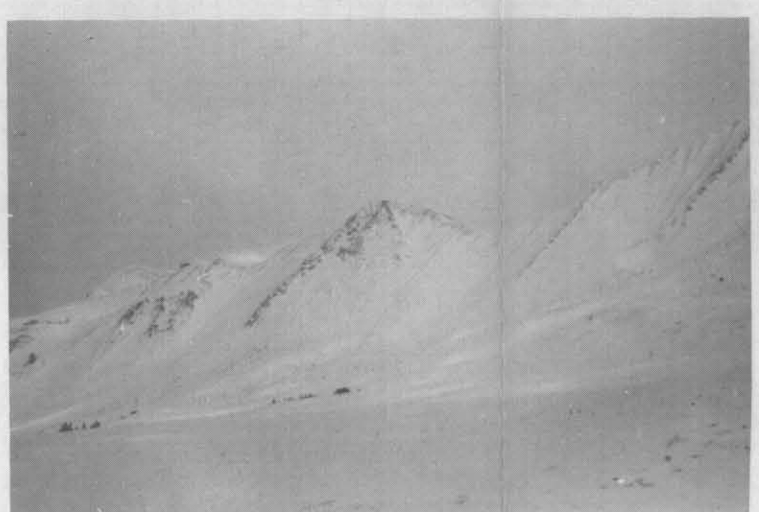
GROSSMAN PEAK
Looking northwest near Location A

GROSSMAN PEAK
Looking to Skeena River from Location A

PANORAMA LAKE
Looking West

PANORAMA LAKE
Looking south to Locations D, E, & F

PANORAMA MOUNTAIN
Location D



PANORAMA MOUNTAIN
Looking east from Locations D, E, & F

PANORAMA MOUNTAIN
Looking north from Locations D, E, & F

EXHIBIT 4

OPERATOR MOUNTAIN
Looking northeast from southwest of Location C

OPERATOR MOUNTAIN
Location C

OPERATOR MOUNTAIN
Looking south from Location C

OPERATOR MOUNTAIN
Looking southwest from Location C

OPERATOR MOUNTAIN
Looking west from Location C

OPERATOR MOUNTAIN
Looking at Kluatantan River from Location C

Looking West at Lonesome Creek

KLUAYAZ LAKE
Looking North

KLUAYAZ LAKE
Looking South

RANGER CREEK 1
Looking southwest

RANGER CREEK 2
Looking west

RANGER CREEK 3
Looking southwest

RANGER CREEK 4
Looking southwest

RANGER CREEK 5
Looking northwest

RANGER CREEK 6
Looking northeast

SKEENA RIVER 7
Flying from Ranger Creek

BEIRNES CREEK
Location G

BEIRNES CREEK
Looking west from Location G

TABULATION 2

PROXIMATE COAL ANALYSES*

The Groundhog Coal Field
British Columbia, Canada
Coastal Coal Co., Ltd.
By
John T. Boyd & Associates
Mining Engineers
December 1966

Location Number	Location	M	V.M.	F.C.	Ash	S	B.T.U.	B.T.U.**	F.C.***	Classi-fication	Thickness Sampled	Sample Origin	Strike	Dip	Total Thickness	Remarks
4	S. Fork, Anthony Creek	4.09	8.48	46.29	41.14	-	-	-	91.4	S.A.	6' 01.5"	Su	N 76° E	17° SE	-	
7	Panorama Creek	3.83	8.80	82.98	4.39	-	-	-	90.9	S.A.	-	-	-	-	10-12'	
10	McEvoy Ridge	2.23	13.73	64.39	19.65	-	-	-	84.6	LVB	-	Su	-	-	12'	Main Section
11A	Augustine Creek	3.75	6.47	62.68	27.10	0.86	10,290	14,679	94.4	An	1' 08"	T	N 52° W	10° NE	3' 08"	Currier No. 2 Seam, 15 ft. drift.
12	Brewer Creek	4.52	4.75	69.93	20.80	2.31	11,900	15,476	96.6	An	3' 10"	T	N 68° W	39° SW	- -	
14	Lower Trail Creek	1.39	5.75	63.02	29.84	1.08	10,541	15,716	95.9	An	6' 08"	T	N 47° W	17° NE	7' 09"	50 ft. slope
15C	Trail Creek	3.20	7.02	49.43	40.35	0.99	7,860	14,100	94.4	An	3' 09"	T	N 67° W	31° NE	7' 00"	Six coal occurrences in 1/2 mile
17A	Little Creek	4.42	6.58	58.96	30.04	1.61	9,930	14,864	94.5	An	2' 04"	Su	N 15° W	25° NE	3' 11"	
18C	Headwaters, Jackson Creek	2.97	5.59	65.60	25.84	1.90	11,520	16,136	95.8	An	4' 05"	T	N 45° W	35° SW	5' 08"	25 ft. drift
19	Mount Jackson	10.16	23.73	45.79	20.32	-	-	-	67.8	-	3' 04"	Su	-	-	-	Weathered
20	Mount Jackson	10.52	22.15	40.81	26.52	-	-	-	67.7	-	6' 02.5"	Su	N 53° W	40° SW	-	
21A	Lower Jackson Creek	6.42	9.83	60.95	22.80	-	-	-	89.1	S - A	7'00"	Su	-	-	-	
22A	Skeena River near Duke Creek	3.66	7.30	53.82	35.22	-	-	-	93.6	An	3' 06"	-	N 64° W	27° NE	-	100 ft. upstream from normal fault
23	Abraham Creek	1.17	6.05	76.20	16.58	0.72	12,215	14,952	94.6	An	6' 00"	T	About East	15° N	-	20 ft. drift
24	Lower Tunnel, Discovery Creek	2.62	6.96	84.49	5.93	0.57	13,814	14,787	93.0	An	6' 02"	T	N 68° E	9° SE	-	16 ft. drift
25	Upper Tunnel, Discovery Creek	1.17	6.54	83.37	8.92	0.74	13,328	14,870	94.9	An	5' 05"+	T	N 22° W	16-23° NE	6' 05"	20 ft. drift
26E	Skeena River	3.84	7,85	51.17	37.14	-	-	-	92.6	An	7' 03"	Su	-	-	-	Folded and faulted area
27A	Mouth of Davis Creek	1.40	6.06	70.68	21,86	1.60	11,788	15,520	94.8	An	4' 00"	T	-	-	-	
28A	Upper Davis Creek	4.72	10.65	72.02	12.61	0.65	-	-	88.5	S-A	4' 06"	Su	N 70° W	NE	Unknown	Floor below water level
30D	Skeena River	3.24	7.67	68.92	20.17	-	-	-	91.9	S-A	-	Su	-	-	Unknown	East bank of Skeena
31C	Anthracite Creek	6.09	13.70	65.52	14.69	-	-	-	84.3	LVB	3' 11.5"	Su	N 88° W	21° S	4' 05.5"	
32B	Scott Seam, Beirnes Creek	1.08	7.06	64.97	26.89	-	-	-	93.8	An	5' 04"	T	NW	Low NE	10' 00"	Cut 35 ft., drift 42 ft.
36A	Seam A, Telfer Creek	3.55	4.02	70.68	21.75	0.99	11,980	15,767	97.5	An	4' 07"	T	N 75° W	65° NE	-	Strike may be wrong
36C	Seam #2, Telfer Creek	3.75	5.74	56.15	34.36	1.57	9,600	15,750	98.1	M-A	4' 03"	T	N 22° W	25° NE	-	450 ft. upstream from "A"; 20 ft. drift
36H	Seam #7, Telfer Creek	5.95	13.32	46.67	34.06	0.44	9,360	14,978	82.5	LVB	3' 06"	T	East	17° N	-	Farthest upstream of 8 seams
39A	Pass E. of Langlois Creek	4.55	5.82	64.84	24.79	1.73	10,030	13,823	95.3	An	3' 06"	T	N 38° W	45° SW	5' or 6'	40 ft. drift
40B	Seam #2, Operator Mountain	4.85	8.30	41.40	45.45	0.21	6,740	13,485	91.7	S-A	4' 00"	Su	N 7° W	27° E	-	
40C	Seam #3, Operator Mountain	12.35	21.20	28.75	37.70	0.82	4,070	6,964	62.3	-	4' 00"	Su	N 35° W	15° NE	5' 07"	Weathered
40D	Seam #4, Operator Mountain	4.65	7.95	46.95	40.45	0.75	9,240	16,669	95.4	An	4' 01.5"	Su	N 50° W	11° NE	-	
40E	Seam #5, Operator Mountain	7.10	13.45	40.60	38.85	0.96	6,580	11,509	81.1	LVB	6' 07.5"	Su	N 56° W	23° NE	7' 11"	
41	Operator Mountain	5.10	5.82	68.43	24.25	1.10	9,550	13,044	95.2	An	3' 00"	Su	N 32° W	88° NE	-	
42A	Ridge, 1.25 mi. NE Oper. Mt.	8.48	12.59	56.70	22.23	1.58	10,340	13,715	84.7	LVB	6' 00"	Su	N 55° W	Vertical	9' 03"	Elevation 5820 ft.
46	Lonesome Creek, 6 ft. seam	2.50	14.6	51.1	27.8	0.8	10,914	15,739	76.4	MVB	-	Su	-	-	-	
46	Lonesome Creek, #2 Seam	3.0	10.7	61.7	24.6	0.6	11,312	15,521	88.3	S-A	-	Su	-	-	-	
47	Creek N. of Kluatuntan Lake	5.85	11.27	41.92	40.95	1.10	5,640	10,284	85.7	LVB	4' 06"	Su	N 35° W	24° SW	-	Dirty coal
49C	East End Mt. Laidlaw	9.95	17.45	30.45	42.15	0.34	5,320	9,925	69.7	-	4' 10"	Su	East	55° S	-	
51	South end, Prudential Mountain	8.85	18.75	28.45	43.95	0.21	7,820	15,146	66.5	-	2' 10"	Su	N 43° W	17° SW	-	
53	Prudential Creek	6.60	15.10	40.85	37.45	0.48	7,050	11,987	78.3	-	3' 09"	Su	North	30° W	4' 11"	
54B	Campbell-Johnson Creek	5.02	6.38	66.95	21.65	-	-	-	94.1	An	6' 00"	Su	N 77° E	34° NW	-	
55	Kluatantun River	4.25	4.35	63.55	27.85	0.62	11,430	16,493	97.7	An	-	Su	N 68° W	63° SW	9' 06"	Overturned syncline
57	Merry Creek	4.0	10.5	72.5	13,0	1.0	12,998	15,184	88.8	S-A	-	Su	-	-	-	A number of seams. Doubtful. location.
58	Kluatantan-Stikine Summit	5.0	11.6	73.6	9.8	0.8	13,464	15,104	87.4	S-A	-	Su	-	-	-	Float only. Inferred location.
59	Ranger Creek	4.0	14.5	72.5	9.0	1.0	13,702	15,224	84.3	LVB	-	Su	-	-	-	Reported many seams.
62	West of Little Klappan River	4.14	8.43	80.27	7.16	-	-	-	91.3	S-A	-	Su	-	-	-	Much crushed seam occurs
63A	Little Klappan River	4.48	9.98	63.48	22.06	-	-	-	88.0	S-A	6' 01.5"	Su	-	-	-	
67	Blume Creek	6.85	13.76	58.08	21,31	-	-	-	83.4	-	-	Su	-	-	9' 00"	Test pitting
68	Porky Creek	5.02	6.38	66.95	21.65	-	-	-	94.2	An	-	Su	-	-	6' 00"	

* Tabulated data taken from The Groundhog Coalfield, A. F. Buckham and B. A. Latour, 1950. Geological Survey of Canada Bulletin 16.
** Moisture and mineral matter free
*** Dry, mineral matter free

Abbreviations:

M	=	Moisture	An	=	Anthracite
V.M.	=	Volatile Matter	S-A	=	Semi-anthracite
F.C.	=	Fixed Carbon	M-A	=	Meta-anthracite
S	=	Sulphur	LVB	=	Low Volatile Bituminous
B.T.U.	=	British Thermal Units	MVB	=	Medium Volatile Bituminous
			Su	=	Surface
			T	=	Tunnel

TABULATION 1

ANALYSES OF COAL SAMPLES*

The Groundhog Coal Field
British Columbia, Canada
Coastal Coal Co., Ltd.

By
John T. Boyd & Associates
Mining Engineers
December 1966

Sample No.	As Received**						Dry**					Ultimate**					
	M	V.M.	F.C.	Ash	S	B.T.U.	V.M.	F.C.	Ash	S	B.T.U.	C	H	O	N	S	Ash
A	22.35	21.35	48.85	7.45	0.33	8,379	27.50	62.91	9.59	0.43	10,791	70.73	2.16	16.02	1.07	0.43	9.59
B	26.68	12.93	14.48	45.91	0.12	2,343	17.63	19.75	62.62	0.16	3,196	25.44	0.87	10.58	0.33	0.16	62.62
B'	27.28	13.21	12.94	46.57	0.09	2,118	18.16	17.80	64.04	0.12	2,913	23.92	0.89	10.66	0.37	0.12	64.04
C	29.24	14.25	14.34	42.17	0.08	2,487	20.14	20.27	59.59	0.12	3,515	27.67	0.90	11.41	0.46	0.20	59.09
C'	28.70	16.21	19.38	35.71	0.14	3,194	22.73	27.18	50.09	0.20	4,479	34.22	1.02	14.01	0.46	0.20	50.09
D	9.97	7.47	55.96	26.60	0.54	9,105	8.30	62.15	29.55	0.60	10,113	63.03	2.26	3.43	1.13	0.60	29.55
E	27.88	13.26	10.43	48.43	0.09	1,702	18.38	14.47	67.15	0.12	2,360	20.47	0.87	11.08	0.31	0.12	67.15
F	22.23	17.93	46.19	13.65	0.33	7,735	23.06	59.39	17.55	0.43	9,946	64.58	1.90	14.33	1.21	0.43	17.55
G	14.17	10.49	70.03	5.31	0.50	11,660	12.22	81.59	6.19	0.58	13,585	83.97	2.79	5.36	1.11	0.58	6.19
H	29.31	16.29	19.11	35.29	0.14	3,094	23.04	27.04	49.92	0.20	4,377	34.69	1.12	13.41	0.66	0.20	49.92

Sample No.	Location	Elevation (Feet)	Strike	Dip	Total Thickness (Inches)	Thickness Sampled	Remarks
A	Grossman Peak	4160	N 35° W	81° SW	65+	15" - Against footwall	Signs of a second seam downgrade.
B	Operator Mountain	5200	-	7° NE	74	74" - Total Seam	
B'	Operator Mountain	5200	-	7° NE	74	36" - Top portion	
C	Operator Mountain	5100	-	11° NE	67	42" - Bottom portion	
C'	Operator Mountain	5100	-	11° NE	67	24" - Top portion	
D	Panorama Mountain	5200	N 48° W	66° NE	62	62" - Total Seam	
E	Panorama Mountain	5200	N 48° W	82° NE	20	20" - Total Seam	50 ft. south of Sample D
F	Panorama Mountain	5200	N 48° W	36° NE	40	40" - Total Seam	150 ft. south of Sample E
G	Beirnes Creek	3820	N 50° W	73° NE	27	23" - Against footwall	At Beirnes Creek edge. Signs of slickenside.
H	Kluayaz Lake	3300	-	-	-	36"	Behind trapper's cabin. Unable to determine strike and dip. Dull coal.

* Samples taken by John T. Boyd & Associates
** Percentages, except for F.S.I.

Abbreviations:

M =	Moisture	C. =	Carbon
V.M. =	Volatile Matter	H =	Hydrogen
F.C.=	Fixed Carbon	O =	Oxygen
S =	Sulphur	N =	Nitrogen
B.T.U. =	British Thermal Units	F.S.I. =	Free Swelling Index (coke button)

POSSIBLE RESERVE AREAS

Geological Findings

OPEN FILE

The ten samples cut on the Johnson-Beaudoin field trip show the following classification:

A	Medium volatile bituminous coal	
D	Semi-anthracite coal	
F	Sub-bituminous medium volatile coal	
G	Semi-anthracite coal	
B	62.91 % ash	Carbonaceous shale
B'	64.04 % ash	" "
C	59.59 % ash	" "
C'	50.09 % ash	" "
E	67.15 % ash	" "
H	49.92 % ash	" "

The coal measures in the Lower Cretaceous Age in the Crows Nest Pass area, British Columbia, which are below the conglomerates have an abundance of carbonaceous shale having a coal appearance.

Of the four samples that are classified as coal, Sample D has a hydrogen to oxygen ratio of 0.65 and Sample G has a hydrogen to oxygen ratio of 0.52 which is indicative of the coal having coking possibilities. Samples A and F are down to a hydrogen to oxygen ratio of 0.13. It must be understood that the samples were taken near the surface and, therefore, the results cannot be considered as conclusive, but they do give some indication of coal quality trends.

Of the 47 samples listed on Tabulation 2 (taken from Bulletin 16 of the Canadian Geological Survey), 17 show low volatile coal and coking possibilities. This is based on the A.S.T.M. "Standard Classification of Coals by Rank". These have moisture and mineral matter free fixed carbon of 69 to 86 percent and plus 14.00 to 22.00 percent volatile matter.

The location of prospect openings where the samples were taken are shown on Exhibit 3 with the location numbers colored yellow.

Of the 17 low volatile prospects with coking coal possibilities, 5 have strata dip gradients of 23° or less; 5 over 23°; and 7 with no dip gradient recorded. The two samples, D and G, taken by Johnson and Beaudoin have dip gradients of 66° and 73°, respectively.

The geological description of the area describes the four anticlinal axes running along the top of the mountains in a northwest direction with major faults having a strike direction of N 60° W. The photographs taken on the field trip by Johnson and Beaudoin show the timberline which is approximately at 4500 ft. elevation. The strata is steeply pitching along the major valleys and in areas such as Operator Mountain and Ranger Creek the strata above the timberline appears to have a gradient under 20°. See Exhibits 4, 5 and 6 for pictures of the area.

Considering the pictures, Malloch's geological description, Bulletin 16 and the Johnson-Beaudoin field trip observations, we have selected five areas which should be investigated, namely: (See Exhibit 3 for location)

Area	Name	Acres
1	Operator Mountain	8,000
2	Mount Laidlaw	30,000
3	Ranger Creek	50,000
4	Mount Gunanoot	50,000
5	McEvoy Ridge	50,000

Two of the five areas, Ranger Creek and Mount Gunanoot, start at major divides, the Skeena-Spatsize Rivers and Kluayetz Creek-Kluatantan River. It is our opinion that in these areas there could be less faulting and more uniform strata than in the other areas. Also, we feel that away from the major fault zones the coal will be of medium to low volatile quality and a sizeable portion of it will be of metallurgical quality.

Reserve Requirements

A mining operation in the Groundhog Area will require a minimum of 100 million recoverable tons of coking coal, or a 4 million ton per year operation for 25 years.

Assuming 10 ft. of metallurgical quality coking coal in one or two seams and 60% mining recovery and 70% preparation plant recovery, the size of the reserve would be:

1800 tons per acre-foot x 10 feet = 18,000 tons of raw coal in place per acre

18,000 tons x 60% x 70% = 7,500 tons recoverable coal per acre (Metallurgical quality)

100 million tons ÷ 7,500 tons per acre = 13,400 acres of coal land

The required acreage will vary with any multiple of 10 feet of coal.

The five possible areas range from 8,000 to 50,000 acres, providing selectivity in choosing the initial mining area.

Exploration

Based on the initial field trip we recommend:

Phase 1:

One geologist and one cameraman with pilot and helicopter to photograph the selected areas. This work should be done with sufficient snow on the ground to give a good contrast of the structure. Allotted time is three weeks including allowance for weather. This time element will permit a limited amount of ground reconnaissance.

Phase 2:

Select the two most likely areas and do a comprehensive geologic mapping on the ground. Allotted time is three months for six geologists and four laborers plus a pilot and helicopter.

The above program will last through the summer. During winter months field work can be mapped in detail.

Phase 3:

After Phase Two personnel have been on the job five weeks, a small core drill will be scheduled to begin operation. The holes should be spotted to be 200 to 800 feet deep. The drills should be equipped with wire cutting core gear for good core recovery. The driller should guarantee coal cores as the quality will be important.

The estimated cost of Phases 1, 2 and 3 will range from $200,000 to $250,000.

At the end of four months the project should be appraised and a determination made as to future money expenditures and method of operation.

Mining Program

The 100 million ton reserve would support an annual production of 4 million tons for 25 years. All tonnage figures are based on low volatile clean coal of metallurgical quality.

The reserve area should have mining conditions with a maximum of 15° gradient and seam height ranging from 5 to 15 feet. This will permit high-speed continuous mining or a combination of development with continuous miners and longwall work for production. The mining conditions will have to permit a minimum of 20 tons of clean coal per man shift.

The estimated cost of equipment replacement is as follows:

Annual Production, tons	4,000,000	
Working Days per Year	225	
Clean Coal per Work Day, tons	17,750	
Reject of Coal Mined, percent	30	
Tons per Man Day	20	
Number of Men Required	900	
Mining Equipment, including preparation plant and power	$60,000,000	
Housing, including utilities and recreation	$12,000,000	
Roads	$ 2,000,000	
Miscellaneous Expense	$ 1,000,000	
Unforeseen Expense (10%)	$ 7,500,000	
Total Estimated Cost		$82,500,000 (US$)

Estimated Production Cost:

Total Out of Pocket Cost	$4.000	
Depreciation		
Original Investment	.835	
Equipment Replacement	.400	
Mine Extension	.100	
Total Cost, before money rental, return on investment and income taxes		$5.335

The estimated realization, f.o.b. ship, Stewart, British Columbia, is $12.50 per ton. This would leave $7.165 per ton for pipeline transportation (120 miles), return on investment and income taxes.

The cost figures and realization are based on U.S. dollars.

ACQUIRING COAL LAND

The regulations governing the mining of coal in British Columbia are set forth in the Coal Act, R.S. 1948, c. 209, S.1.

All coal in the Groundhog Coalfield of British Columbia belongs to the Crown. There are two methods of obtaining the right to mine this coal:

1. Coal Lease:

Under the terms of a coal lease, the lessee agrees to produce not less than 10,000 tons nor more than 100,000 tons of coal per year. The term of a lease is for 20 years. Successive renewals are obtainable for 20-year periods, or less if the coal reserves are exhausted within the period. A lessee may acquire as many leases as are needed for the size of the operation. A lease is granted only after the location has been held under a license and the annual tonnage has been increased to at least 10,000 tons of coal. All of the work required to be done on a group of leases may be done in any one or more of the leases. A lease location shall be one square mile in area unless the coal land is of less area. The lease shall be square in form unless the coal land is less than one square mile in area. In surveyed territory the boundaries of the lease shall conform to the boundaries of sections, lots or legal subdivisions; in unsurveyed territory the boundaries shall run north and south and east and west and bearings shall be astronomic. A lessee shall not commence mining operations without first submitting a plan of the operation to and obtaining the approval of the Chief Inspector of Mines. Each lessee shall pay a royalty of 25¢ on every ton of coal shipped, exported, or in any way delivered from the location. This royalty shall be paid monthly. The rental for a lease shall be $1.00 per acre, per annum, payable yearly in advance. The fee for the issuing of a lease and for a renewal of a lease is $25.00 for each lease.

2. Coal License:

A legal post must be firmly planted in the ground at the southeast corner of the location. Another legal post must be planted in a conspicuous place in the location which will denote the distance and direction to the southeast corner. An application for a license in unsurveyed territory shall be made within 30 days after the date upon which the tract applied for was staked. A licensee will undertake to do development work and mine coal according to a plan of operation approved by the Chief Inspector of Mines. A license is governed by the same dimensions as a lease and a licensee may hold as many licenses as required for his operation. The rental for a license shall be 50¢ per acre in addition to the royalties of 25¢ per ton of coal shipped. If development work of $7.50 or more per acre is done, the 50¢ rental shall be rebated. The fee for a license or a renewal after each one year period is $25.00.

Summation

One Sq. Mile Area	Period (year)	Royalty Per Ton	Yearly Rental		Issuing and Renewal Fee
			Per Acre	Total	
Lease	20	$0.25	$1.00	$640.00	$25.00
License	1	$0.25	$0.50	$320.00	$25.00

Note: A license must be issued before a lease can be applied for.

The cost of a license for exploration work is $25.00 per square mile plus $0.50 per acre rental and royalty of 25¢ per ton when coal is mined. A lease can be obtained for a 20-year period at the rate of $1.00 per acre per year plus a 25¢ per ton royalty. The issuing of a lease is $25.00 per square mile.

Appendix

Exhibits

407-A REV.

PITTSBURGH TESTING LABORATORY

ESTABLISHED 1881

PITTSBURGH, PA.

LABORATORY NO. 647233

ORDER NO. PG-14121

CLIENT'S NO.

REPORT

November 28, 1966

J.T.B. & ASSOCIATES
"B"

Analysis of: COAL

Marked: #2 Location, No. 1073

Submitted by: John T. Boyd & Associates

Reported to: John T. Boyd & Associates
1319 Oliver Building
Pittsburgh, Pa. 15222

	As Received	Dry Basis
Moisture	26.68%	---------
Volatile Matter	12.93%	17.63%
Fixed Carbon	14.48%	19.75%
Ash	45.91%	62.62%
Sulfur	0.12%	0.16%
BTU Per Pound	2,343	3,196
Carbon	------	25.44%
Hydrogen	------	0.87%
Oxygen	------	10.58%
Nitrogen	------	0.33%
Sulfur	------	0.16%
Ash	------	62.62%
Free Swelling Index	1 (Non Caking)	

PITTSBURGH TESTING LABORATORY

Robert J. King
Manager, Chemical Division

3 - Client
Attn: L. M. Thomas

mak

407-J REV.

PITTSBURGH TESTING LABORATORY

ESTABLISHED 1881

PITTSBURGH, PA.

LABORATORY NO. 647235

ORDER NO. PG-14121

CLIENT'S NO.

REPORT

November 28, 1966

J.T.B. & ASSOCIATES
"A"

Analysis of: COAL

Marked: #1 Location, No. 1068

Submitted by: John T. Boyd & Associates

Reported to: John T. Boyd & Associates
1319 Oliver Building
Pittsburgh, Pa. 15222

	As Received	Dry Basis
Moisture	22.35%	---------
Volatile Matter	21.35%	27.50%
Fixed Carbon	48.85%	62.91%
Ash	7.45%	9.59%
Sulfur	0.33%	0.43%
BTU Per Pound	8,379	10,791
Carbon	------	70.73%
Hydrogen	------	2.16%
Oxygen	------	16.02%
Nitrogen	------	1.07%
Sulfur	------	0.43%
Ash	------	9.59%
Free Swelling Index	1 (Non Caking)	

PITTSBURGH TESTING LABORATORY

Robert J. King
Robert J. King
Manager, Chemical Division

3 - Client
Attn: L. M. Thomas

mak

407-A REV.

PITTSBURGH TESTING LABORATORY

ESTABLISHED 1881

PITTSBURGH, PA.

LABORATORY NO. 647237

CLIENT'S NO.

ORDER NO. PG-14121

REPORT

November 28, 1966

J.T.B. & ASSOCIATES
"B' "

Analysis of: COAL

Marked: No. 2 Location, No. 1070

Submitted by: John T. Boyd & Associates

Reported to: John T. Boyd & Associates
1319 Oliver Building
Pittsburgh, Pa. 15222

	As Received	Dry Basis
Moisture	27.28%	---------
Volatile Matter	13.21%	18.16%
Fixed Carbon	12.94%	17.80%
Ash	46.57%	64.04%
Sulfur	0.09%	0.12%
BTU Per Pound	2,118	2,913
Carbon	------	23.92%
Hydrogen	------	0.89%
Oxygen	------	10.66%
Nitrogen	------	0.37%
Sulfur	------	0.12%
Ash	------	64.04%
Free Swelling Index	1 (Non Caking)	

PITTSBURGH TESTING LABORATORY

Robert J. King
Manager, Chemical Division

3 - Client
Attn: L. M. Thomas

mak

407-K REV.

PITTSBURGH TESTING LABORATORY

ESTABLISHED 1881

PITTSBURGH, PA.

LABORATORY NO. 647238

CLIENT'S NO.

ORDER NO. PG-14121

REPORT

November 28, 1966

J.T.B. & ASSOCIATES
"C"

Analysis of: COAL

Marked: #3 Location, No. 1071

Submitted by: John T. Boyd & Associates

Reported to: John T. Boyd & Associates
1319 Oliver Building
Pittsburgh, Pa. 15222

	As Received	Dry Basis
Moisture	29.24%	---------
Volatile Matter	14.25%	20.14%
Fixed Carbon	14.34%	20.27%
Ash	42.17%	59.59%
Sulfur	0.08%	0.12%
BTU Per Pound	2,487	3,515
Carbon	------	27.67%
Hydrogen	------	0.90%
Oxygen	------	11.41%
Nitrogen	------	0.31%
Sulfur	------	0.12%
Ash	------	59.59%
Free Swelling Index	1 (Non Caking)	

PITTSBURGH TESTING LABORATORY

Robert J. King
Manager, Chemical Division

3 - Client
Attn: L. M. Thomas

mak

407-A REV.

PITTSBURGH TESTING LABORATORY

ESTABLISHED 1881

PITTSBURGH, PA.

LABORATORY NO. 647236

CLIENT'S NO.

ORDER NO. PG-14121

REPORT

November 28, 1966

Analysis of: COAL

J.T.B. & ASSOCIATES "C'"

Marked: #6 Location, No. 1069

Submitted by: John T. Boyd & Associates

Reported to: John T. Boyd & Associates
1319 Oliver Building
Pittsburgh, Pa. 15222

	As Received	Dry Basis
Moisture	28.70%	---------
Volatile Matter	16.21%	22.73%
Fixed Carbon	19.38%	27.18%
Ash	35.71%	50.09%
Sulfur	0.14%	0.20%
BTU Per Pound	3,194	4,479
Carbon	------	34.22%
Hydrogen	------	1.02%
Oxygen	------	14.01%
Nitrogen	------	0.46%
Sulfur	------	0.20%
Ash	------	50.09%
Free Swelling Index	1 (Non Caking)	

PITTSBURGH TESTING LABORATORY

Robert J. King,
Manager, Chemical Division

3 - Client
Attn: L. M. Thomas

mak

407-A REV.

PITTSBURGH TESTING LABORATORY

ESTABLISHED 1881

PITTSBURGH, PA.

LABORATORY NO. 647234

CLIENT'S NO.

ORDER NO. PG-14121

REPORT

November 28, 1966

J.T.B. & ASSOCIATES
"D"

Analysis of: COAL

Marked: #5 Location, No. 1072

Submitted by: John T. Boyd & Associates

Reported to: John T. Boyd & Associates
1319 Oliver Building
Pittsburgh, Pa. 15222

	As Received	Dry Basis
Moisture	9.97%	---------
Volatile Matter	7.47%	8.30%
Fixed Carbon	55.96%	62.15%
Ash	26.60%	29.55%
Sulfur	0.54%	0.60%
BTU Per Pound	9,105	10,113
Carbon	------	63.03%
Hydrogen	------	2.26%
Oxygen	------	3.43%
Nitrogen	------	1.13%
Sulfur	------	0.60%
Ash	------	29.55%
Free Swelling Index	1 (Non Caking)	

PITTSBURGH TESTING LABORATORY

Robert J. King
Manager, Chemical Division

3 - Client
Attn: L. M. Thomas

mak

407-A REV.

PITTSBURGH TESTING LABORATORY

ESTABLISHED 1881

PITTSBURGH, PA.

LABORATORY NO. 647230

CLIENT'S NO.

ORDER NO. PG-14121

REPORT

November 28, 1966

J.T.B. & ASSOCIATES
"E"

Analysis of: COAL

Marked: #7 Location, No. 1076

Submitted by: John T. Boyd & Associates

Reported to: John T. Boyd & Associates
1319 Oliver Building
Pittsburgh, Pa. 15222

	As Received	Dry Basis
Moisture	27.88%	---------
Volatile Matter	13.26%	18.38%
Fixed Carbon	10.43%	14.47%
Ash	48.43%	67.15%
Sulfur	0.09%	0.12%
BTU Per Pound	1,702	2,360
Carbon	------	20.47%
Hydrogen	------	0.87%
Oxygen	------	11.08%
Nitrogen	------	0.31%
Sulfur	------	0.12%
Ash	------	67.15%
Free Swelling Index	1 (Non Caking)	

PITTSBURGH TESTING LABORATORY

Robert J. King
Manager, Chemical Division

3 - Client
Attn: L. M. Thomas

mak

407-A REV.

PITTSBURGH TESTING LABORATORY

ESTABLISHED 1881

PITTSBURGH, PA.

LABORATORY NO. 647232

ORDER NO. PG-14121

CLIENT'S NO.

REPORT

November 28, 1966

J.T.B. & ASSOCIATE
"F"

Analysis of: COAL

Marked: #4 Location, No. 1075

Submitted by: John T. Boyd & Associates

Reported to: John T. Boyd & Associates
1319 Oliver Building
Pittsburgh, Pa. 15222

	As Received	Dry Basis
Moisture	22.23%	---------
Volatile Matter	17.93%	23.06%
Fixed Carbon	46.19%	59.39%
Ash	13.65%	17.55%
Sulfur	0.33%	0.43%
BTU Per Pound	7,735	9,946
Carbon	------	64.58%
Hydrogen	------	1.90%
Oxygen	------	14.33%
Nitrogen	------	1.21%
Sulfur	------	0.43%
Ash	------	17.55%
Free Swelling Index	1 (Non Caking)	

PITTSBURGH TESTING LABORATORY

Robert J. King
Manager, Chemical Division

3 - Client
Attn: L. M. Thomas

mak

PITTSBURGH TESTING LABORATORY

ESTABLISHED 1881

PITTSBURGH, PA.

LABORATORY NO. 647231

CLIENT'S NO.

ORDER NO. PG-14121

REPORT

November 28, 1966

J.T.B. & ASSOCIATES
"G"

Analysis of: COAL

Marked: #9 Location, No. 1074

Submitted by: John T. Boyd & Associates

Reported to: John T. Boyd & Associates
1319 Oliver Building
Pittsburgh, Pa. 15222

	As Received	Dry Basis
Moisture	14.17%	---------
Volatile Matter	10.49%	12.22%
Fixed Carbon	70.03%	81.59%
Ash	5.31%	6.19%
Sulfur	0.50%	0.58%
BTU Per Pound	11,660	13,585
Carbon	------	83.97%
Hydrogen	------	2.79%
Oxygen	------	5.36%
Nitrogen	------	1.11%
Sulfur	------	0.58%
Ash	------	6.19%
Free Swelling Index	1 (Non Caking)	

PITTSBURGH TESTING LABORATORY

Robert J. King
Manager, Chemical Division

3 - Client
Attn: L. M. Thomas

mak

407-A*REV.

PITTSBURGH TESTING LABORATORY

ESTABLISHED 1881

PITTSBURGH, PA.

LABORATORY NO. 647229

CLIENT'S NO.

ORDER NO. PG-14121

REPORT

November 28, 1966

J.T.B. & ASSOCIATES
"H"

Analysis of: COAL

Marked: #8 Location, No. 1077

Submitted by: John T. Boyd & Associates

Reported to: John T. Boyd & Associates
1319 Oliver Building
Pittsburgh, Pa. 15222

	As Received	Dry Basis
Moisture	29.31%	---------
Volatile Matter	16.29%	23.04%
Fixed Carbon	19.11%	27.04%
Ash	35.29%	49.92%
Sulfur	0.14%	0.20%
BTU Per Pound	3,094	4,377
Carbon	------	34.69%
Hydrogen	------	1.12%
Oxygen	------	13.41%
Nitrogen	------	0.66%
Sulfur	------	0.20%
Ash	------	49.92%
Free Swelling Index	1 (Non Caking)	

PITTSBURGH TESTING LABORATORY

Robert J. King
Manager, Chemical Division

3 - Client
Attn: L. M. Thomas

mak

[illegible] 1/8/79.

Gen-GROUND HOG 66(1)A

Gen-Groundhog 66 (1) A

JOHN T. BOYD & ASSOCIATES

MINING ENGINEERS AND GEOLOGISTS

JOHN T. BOYD
ROBERT L. FRANTZ

OLIVER BUILDING - MELLON SQUARE

PITTSBURGH, PENNSYLVANIA 15222

CONSULTANTS
DESIGNS AND REPORTS

January 25, 1967

412-281-1219

Coastal Coal Co., Ltd.
5383 Granville Street
Vancouver, British Columbia

Attention: Mr. Austin G. E. Taylor

Dear Sirs:

In this cover is our report on the Groundhog Coalfield, British Columbia, Canada. The area, covering approximately 150 square miles, is located 150 miles north of Hazelton and 95 miles northeast of Stewart in the Cassiar District.

Mr. E. P. Johnson, of John T. Boyd & Associates, and Mr. Armand Beaudoin, of Coastal Coal Co. Ltd., spent October 6 through 10, 1966, in the area studying general conditions and obtaining coal samples.

The result of this field trip and an analysis of all available facts and pertinent data have led to the conclusions of the engineer-writers as presented in this report.

Very truly yours,

John T. Boyd
John T. Boyd

Table of Contents

TABLE OF CONTENTS

GENERAL STATEMENT

The Groundhog Coalfield is located in one of the most inaccessible sections of British Columbia. At the present time the only means of access to this area is by packhorse or helicopter. There is a dry weather road along the Bell Irving River 40 miles southwest of the area.

The summer climate is cool and wet with temperatures ranging from 26 to 84 degrees F., whereas the winter climate has a low of minus 40° F. and averages minus 20° with 4 to 8 feet of snow. Snow can be expected in the area from mid-September to mid-June which provides a minimum period of good weather for prospecting.

Between 1904 and 1912 prospecting and development work was carried on in the area. At that time it was considered the largest area in Canada underlain by anthracite coal.

In 1948, A. F. Buckham and B. A. Latour of the Department of Mines and Technical Surveys, Geological Survey of Canada, began a resurvey of the field. They accumulated all available data and together with the results of the summer's field work published Bulletin 16, "The Groundhog Coalfield, British Columbia".

The report showed information on 192 occurrences of coal seams with proximate analysis work done on 47 samples, as shown on Tabulation 2 of this report. In addition, during the October 1966 field trip of Johnson and Beaudoin 10 samples were obtained. Proximate and ultimate analyses determinations were made and the results are shown on Tabulation 1 of this report.

To develop an economically mineable coal reserve in the Groundhog area will require,

(a) Rail or pipeline transportation to the seaport at Stewart, British Columbia.

(b) All weather road to Stewart.

(c) Communications

(d) Housing with complete townsite facilities in the Groundhog area.

Capital expenditure for the above would require a minimum of 100 million recoverable tons of metallurgical quality coal which could be mined for a maximum production cost of $5.00 per ton.

The engineer-writers of this report develop the exploration requirements and evaluate the possibilities of developing a large economical coal reserve of metallurgical quality.

Respectfully submitted,

JOHN T. BOYD & ASSOCIATES

By:

A. G. Gilbert

A. G. Gilbert

Elmer P. Johnson

Elmer P. Johnson

John T. Boyd

John T. Boyd

SUMMARIZED FINDINGS

The following sections of this report, together with the tabulations and the exhibits, support these summarized statements.

±1500

1. The Groundhog Coalfield covers an area of 150 square miles. It is 150 miles north of Hazelton and 95 miles northeast of Stewart, British Columbia.

2. The only access to the Groundhog Coalfield is by helicopter or packhorse. The nearest dry weather road is reported to be 40 miles northwest along the Bell-Irving River.

3. Summer climate is cool and wet with temperatures ranging from 26 to 84 degrees Fahrenheit. Winter temperatures average minus 20 degrees Fahrenheit. Snow ranges from 4 to 8 feet in thickness.

4. From 1904 through 1912 extensive prospecting work was carried on in the area. In 1948 the Geological Survey of Canada made a resurvey of the field. By accumulating all available data and the one summer's work, they published Bulletin 16. It describes the general geology of the area, tells of 192 observed coal occurrences and has analytical data on 108 samples; some areas have sample duplication. This report tabulated information on 47 of these samples (see Tabulation 1).

5. There has not been sufficient field work done to construct a geological map of the Groundhog Area locating the major faults and general structure.

6. The geologic structure of the Groundhog Field is complex. In general, the strata appears to lie in folds overturned to the northeast whose axes strike to the northwest, with general dip of strata to the southwest, though locally measures can dip to the northeast. The main rivers and mountain ranges are in a northwest-southeast direction with the top of the mountain ranges anticlinal. With the folding there are major faults which have strikes of approximately N 60 W.

7. The classification of coals by rank, as approved by the American Standards Association, are:

Class of Coal	Fixed Carbon*	Volatile*
Anthracite	92 to 98 %	2 to 8 %
Semi-anthracite	86 to 92 %	8 to 14 %
Low volatile bituminous	78 to 86 %	14 to 22 %
Medium volatile bituminous	69 to 78 %	22 to 31 %
High volatile bituminous**	Minus 69 %	Plus 31 %

* Mineral matter free basis.
** Minimum of 14,000 B.t.u. with natural bed moisture.

Note: The above classifications can be made from proximate analysis of coals.

8. The second determining factor is oxygen content. Coke of best quality is made from coals of relatively low oxygen content or having a hydrogen-oxygen ratio of .60 or more with a minimum of .55. This determination requires an ultimate analysis of the coals.

9. Of the 47 coal prospect areas having proximate analysis made, 17 show low to medium volatile coking coal characteristics (marked yellow on Exhibit 3 tabulation).

10. On the Johnson-Beaudoin field trip in October 1966, ten samples were cut and analyzed. Samples A, D, F and G were coal with the balance of the samples carbonaceous shale.

11. Sample G (Beirnes Creek) had a .52 hydrogen to oxygen ratio and Sample D (Panorama Mountain) had .65 hydrogen to oxygen ratio. The coals, however, are in the semi-anthracite classification.

12. "Selection of Coals for Coking" from Fuels and Combustion Handbook states that up to 10% of anthracite coal can be used as a blend in coke making to an advantage; however, in the United States a very limited amount is used; this could be due to the cost of mining and freight rates.

13. The writers of this report believe that low to medium volatile metallurgical coking coal is available in the Groundhog Coalfield. Most of the prospect openings have been along the major valleys and thus could be along major faults. The strata in most cases is steeply pitching and has been subject to great pressure.

14. Five potential areas are located (see Exhibit 3); these should be investigated. The areas are:

Operator Mountain	8,000 acres
Mount Laidlaw	30,000 acres
Ranger Creek	50,000 acres
Mount Gunanoot	50,000 acres
McEvoy Ridge	50,000 acres

15. Due to the location of the Groundhog Coalfield, it will require a minimum of 4 million tons of low volatile metallurgical coal per year to support a pipeline or railroad to Stewart, British Columbia, a seaport. This production requires a mineable coal reserve of 100 million recoverable tons.

16. To develop a 100 million ton coal reserve requires an extensive exploration program. The first summer's work is divided into three phases at an estimated cost of $200,000 to $250,000.

17. The estimated required capital expenditure to install a mine with 4 million tons annual capacity is $82,500,000. This cost includes housing, coal preparation and mining equipment, but does not include the railroad or pipeline to Stewart. This estimate is preliminary and would need to be worked in detail after the reserve is proven.

18. The coal reserve should have a gradient of under 15 degrees. This will permit high-speed mining with either continuous or longwall mining methods. The geological conditions will have to permit 20 tons per man day to make the project feasible.

19. The estimated production cost is,

Total Out of Pocket Cost	$4.000
Depreciation - Original Investment	.835
Equipment Replacement	.400
Mine Extension	.100
Total Cost (before money rental, return on investment and income taxes)	$5.335

20. The estimated realization, f.o.b. ship, Stewart, is $12.50 per ton. This would leave $7.165 per ton for pipeline transportation (120 miles), return on investment and income taxes.

All cost figures and realization are based on U.S. dollars.

GENERAL GEOLOGY
Groundhog Area

The rocks of the Groundhog Area consist of a thick succession of conglomerates, sandstone, shale, coal and beds gradational between these types. The succession is a monotonous alteration chiefly of sandstone and shale not readily divisible into well-defined formations.

Malloch, a geologist, split the rocks of the Groundhog Area into a lower and upper part of the Hazelton Group with the upper strata being of the Skeena series. The Hazelton Group was thought to be Jurassic, the Skeena series, Lower Cretaceous, and the boundary between was placed somewhat arbitrarily just below the coarse crumbly conglomerates. The coal seams are thought to be confined to the Skeena series. There appears to be a correlation with the Kootenay and Lower Blairmore of Alberta of the Lower Cretaceous Age. The best coal appears to occur in rocks of the Blairmore Formation.

The geologic structure of the Groundhog Field is complex and is difficult to describe. In general, the strata appears to lie in folds overturned to the northeast whose axes strike to the northwest, with the general dip of the strata to the southwest, though locally measures can dip to the northeast. With the folding there has been pronounced faulting with the general strike N 60° W and in many cases in the nature of thrust faults.

The main rivers and mountain ranges are in a northwest-southeast direction with the top of the mountain ranges anticlinal which substantiates Malloch's geological description.

Malloch describes the general geological structure of the Groundhog Field as follows:

There is a somewhat close correspondence between the main topographic forms exhibited in the field and the geological structure. Four mountain ranges are present in the district and strike northwest parallel with one another and with the three longitudinal valleys that traverse the district. The most easterly of these ranges forms the northeast slope of the Kluatantan River-Kluayetz Creek longitudinal valley. The next range to the west lies between the Kluatantan River-Kluayetz Creek and the Skeena-Spatsizi longitudinal valley; the third range borders the Skeena-Spatsizi valley on the southwest; the fourth range borders the Nass longitudinal valley on the northeast and is separated from the third range by a depression.

Each of these four ranges has, in places at least, broad summits cut by deep transverse cirques. The bounding slopes are steep and each range presents the same broadly developed geological structure. In each case the southwestern slopes consist of strata of the two lower groups of the Skeena series, dipping to the southwest at angles of 30 to 40 degrees. These measures appear to form the western limbs of overturned anticlines. On the summits of the ranges, strata of the lower portion of the Skeena series are exposed also, but dip and strike in various directions and, as a rule, with much lower angles of dip. These measures presumably lie close to the plane of the main anticlines expressed by the ridges, but are, in general, separated by thrust faults from the more regularly dipping strata on the southwestern slopes of the ranges.

The irregularly dipping strata of the summits are in their turn thrust northeastward over another fault block which in the case of the range lying east of the Kluatantan River-Kluayetz Creek valley, belongs to the Hazelton group which outcrops along the northeastern border of the field and marks, in a general way, the position of the main anticlinal axis of this range. In the case of the next mountain range to the west, lying between the Kluayetz Creek-Kluatantan and the Skeena-Spatisizi valleys, the position of the main anticlinal axis is indicated in part by outcrops of the Hazelton group occurring along a sinuous band, striking to the northwest along the northeastern slopes of the range. The third major anticlinal expressed by the range bordering the Skeena-Spatisizi valley on the west, is also indicated by an irregular bankline area of the Hazelton group striking to the northwest along the southwestern summit of this range. The fourth major anticlinal axis, developed in the lower strata of the Skeena series, follows the southwestern side of the summits of the range bordering the Nass valley on its northeastern side.

The northeastern slope of the anticlinal range bordering the field on the east was not visited, but presumably exhibits the same general structures believed to be present in the three parallel ranges lying to the west within the limits of the coalfield. In the case of these three main ridges on their northeastern slopes below the major anticlinal axes, the strata belonging to various divisions of the Skeena series dip in general to the southwest, and apparently form the eastern overturned limb of the major anticlines, but these measures are also traversed by thrust faults and furthermore in places at least are bent in major or minor synclines.

The four mountain ranges are thus believed to represent, in a general way, overturned major anticlinal folds deformed by thrust faults and minor crumples and folds. The three main, longitudinal valleys and the parallel depressed area lying between the Skeena-Spatsizi and the Nass valleys, are believed to mark, in an analogous fashion, the positions of the major synclines along which, in general, the strata are less steeply inclined than on the limbs of the folds. These synclinal portions are doubtless bounded by thrust faults and are deformed by minor crumples and folds, but the geological structures are not clearly exposed in these overlying areas where drift and forest growth hide the bedrock.

The above description gives, in a generalized fashion, an outline of the major structural features of the field. But, owing to the presence of minor crumples and folds and perhaps more especially because of the presence of the numerous thrust faults which do not strike parallel with the main axes of folding but cut across the axial lines at an acute angle, there are many exceptional features that apparently do not correspond with the general plan. For instance, the range lying west of the Skeena-Spatsizi divide is capped by strata of the highest group (No. 1) of the Skeena series forming an area 4 to 6 miles wide, in which the strata generally exhibit a flat synclinal structure, but, in common with the rest of the field, are crossed by faults.

Although the general strike of the strata is northwest, there are thrust faults which strike more acutely approximately N 60° W which complicate the general structure. In almost all of the cases, the faults are marked by steeply dipping beds resulting from the drag effect of the faulting. The beds near the fault line exhibit the pronounced metamorphism and in many cases where coal seams occur in this steeply inclined strata, the coal is crushed to powder and intimately mixed with fragments of shale as though there had been differential movement between the beds on each side.

There has not been sufficient geological work done in the Groundhog reserve area to actually locate the anticlines, synclines, major faults, and other geological features which would permit mapping of the area.

Figure 1, following this text, shows typical geologic structure of the central part of the Rocky Mountains in the vicinity of the Crows Nest Pass Coalfield. This area is 750 miles southeast of Groundhog with the coal seams being of medium and low volatile coals; a portion of the seams has good coking characteristics. The Kootenay coal-bearing formation is colored red on the sections.

PRESENTATION OF THE EXHIBITS

All of the report's exhibits are enclosed in the Exhibit Section of the report. This chapter presents the exhibits individually with explanatory text.

The exhibits are:

Exhibit 1: Scale, 1" = 30 miles

General map of a major portion of British Columbia and Alberta and a portion of southeastern Alaska. The exhibit is a photograph of a Department of Lands, Forests and Water Resources, British Columbia, map and shows,

1. General outline of the Groundhog Coalfield
2. Proposed routes for pipeline or rail to sea water.
3. Seaport of Stewart, British Columbia and Portland Canal to the Pacific Ocean.
4. Helicopter route from Smithers, British Columbia, to the Groundhog Coalfield.

Exhibit 2: Scale, 1" = 4 miles

Map of the Groundhog Coalfield showing,

1. Location of
   a. Approximate Groundhog boundary
   b. Proposed pipeline or rail route
   c. Helicopter route traveled by John T. Boyd & Associates
   d. Land recording district boundaries.
   e. Reserve 0253450 boundaries.
   f. Areas sampled by John T. Boyd & Associates
   g. Proposed drill holes
   h. Possible town and plant site location.
2. Contour lines on 500 ft. intervals and streams, lakes and rivers.
3. Inset with tabulated sample analysis date (see Exhibits 2 and 3 for location).

<u>Exhibit 3:</u> Scale, 1" = 8000 feet

Map of the Groundhog Coalfield showing

1. Location of
   a. Approximate boundary of Groundhog Coalfield.
   b. Sampled areas described in Bulletin 16 with analysis, B.t.u.'s, seam thickness, strike and dip recorded.
   c. Areas sampled by John T. Boyd & Associates

2. Contour lines on 500 ft. intervals and streams, lakes and rivers.

3. Possible areas of low volatile, metallurgical coal.

<u>Exhibit 4:</u> Not to Scale

Photographs of the Groundhog Coalfield area showing

1. Grossman Peak area

2. Panorama Lake area

3. Panorama Mountain area

<u>Exhibit 5:</u> Not to Scale

Photographs of the Groundhog Coalfield area showing

1. Operator Mountain area

2. Lonesome Creek

3. Kluayaz Lake area

<u>Exhibit 6:</u> Not to Scale

Photographs of the Groundhog Coalfield area showing

1. Rangers Creek area

2. Skeena River from Ranger Creek

3. Beirnes Creek area

GROUNDHOG RESERVE AREA FIELD STUDY
October 1966

Messrs. E. P. Johnson of John T. Boyd & Associates and Armand Beaudoin of Coastal Coals Inc. worked on the Groundhog coal reserves from October 4 through October 10, 1966.

On October 4, 1966, a preliminary meeting was held in the Hill-Manning and Associates office in Vancouver, British Columbia. Attending the meeting were,

Henry Hill	Director, Coastal Coals Inc.
Armand Beaudoin	Geologist, Coastal Coals Inc.
E. P. Johnson	John T. Boyd & Associates
John T. Boyd	John T. Boyd & Associates

Mr. Beaudoin had previously spent several days in the Groundhog Area. Pictures and coal samples obtained were viewed and discussed. The Johnson-Beaudoin trip to Victoria and the Groundhog Area was outlined and discussed.

Following is a chronological log of the Groundhog field trip by Mr. E. P. Johnson.

October 5: A meeting was held in Victoria, British Columbia, with Mr. Ken Blakey, Deputy Minister of Mines; attending were Henry Hill, Armand Beaudoin, Harry Bell-Irving and E. P. Johnson. Mr. Brothers, Minister of Mines, was not in his office on that date. Mr. Blakey agreed to recommend to a higher authority that Coastal Coal Co. Ltd., be allowed three years' work in the Groundhog Coalfield without interference from other coal prospectors.

October 6: Armand Beaudoin, Pilot W· yne Grover and E. P. Johnson left Smithers, British Columbia, in a helicopter and flew to Kluayaz Lake by the route shown on Exhibit 1. Left Smithers at 11:15 AM and arrived at Kluayaz Lake at 3:30 PM, making one stop for fuel.

October 6: (Continued) Flew reconnaissance over general area in vicinity of Operator Mountain. Walked down stream bed on Mount Gordon. Apparently four coal seams here at elevations 5380, 5180, 5150 and 4800 feet. Seams steeply pitching about 75° east; strike of seams N 15 W. Observed low seam of coal at Grizzly Gulch; observed coal seams at Grossman Peak.

October 7: Weather bad. Landed by Lonesome Creek and looked for reported coal seam. Ground cover heavy and marshy here; unable to locate coal.

Snowing on Kluayaz Lake where we stayed at the cabin of Colby Wookey, a trapper.

October 8: Sampled a seam at Grossman Peak, elevation 4160 feet and steeply pitching. Ground now covered with snow and seam difficult to locate. Apparently another seam downgrade from sampled seam.

Sampled two seams near Grizzly Gulch in Operator Mountain; one at 5200 ft. elevation (Samples B and B'); one at 5100 ft. elevation (Samples C and C'). These seams appear to form a gentle syncline on Operator Mountain. This would be a good area for a mining operation.

October 9: Snowing; finally cleared at 2:30 PM and we were able to go to Panorama Pass. Sampled three steeply pitching seams on Panorama Mountain: Samples D, E' and F.

October 10: Cloudy and snowing. Flew to Ranger Creek and traversed some of the area on foot. Snow on ground and unable to see any signs of coal seams. Structure fairly flat. Good mining area.

Flew over pass to Skeena River and then to Beirnes Creek. Took Sample G here of steeply pitching seam.

Attempted to get to McEvoy Ridge but weather too bad for helicopter.

Took sample of coal from seam behind trapper's cabin on Kluayaz Lake, Sample H. Mr. Wookey had dug channel but not far enough to determine strike and dip. Coal burned as forge coal, a bright cherry red, maintaining heat.

Left Kluayaz Lake at 3:00 PM and arrived at Smithers at 6:00 PM. Stopped to refuel at Second Cabin on Telegraph Trail.

October 11: Traveled from Smithers to Vancouver for preliminary meeting at 3:00 PM.

Most favorable area observed for mining was Operator Mountain. Two seams observed with possible 25 million tons of reserve.

During the field trip, Johnson and Beaudoin cut ten (10) coal samples. In most cases the sample locations were covered with snow and it was difficult to face up a fresh solid face of coal.

Following this text is Tabulation 1 showing,

(1) Sample location and elevation. (See Exhibit 3 for field location.)

(2) Strike and dip of seam and coal thickness sampled.

(3) Proximate analysis on as received and dry basis.

(4) Ultimate analysis of coal seams.

Bulletin 16 of the Geological Survey of Canada, "The Groundhog Coalfield", lists 108 prospect locations where the coal was sampled and classified. The samples range in quality as follows:

Moisture	1.04 to 12.50 %
Volatile Matter	1.07 to 23.73 %
Fixed Carbon	30.45 to 84.00 %
Ash	4.05 to 45.45 %
Sulphur	0.16 to 3.05 %
B.t.u.'s	4,070 to 14,216

From the 108 analyses listed in Bulletin 16, Mr. Johnson has listed 47 representative samples on Tabulation 2 showing,

(a) Prospect location numbers located on Exhibit 3.

(b) Proximate analysis and sulphur on an as received basis.

(c) B.t.u.'s on as received and dry basis.

(d) Sample thickness, origin, strike, dip and type of sample.

Following Tabulation 2 are,

1. "Specifications for Classification of Coals by Rank" by The American Standards Association.

2. "Selection of Coals for Coking", from Fuels and Combustion Handbook, by A. J. Johnson and George H. Auth, pages 148 through 159.

APPROVED AS
AMERICAN STANDARD
BY THE AMERICAN STANDARDS ASSOCIATION
ASA NO.: M20.1-1938

Standard Specifications for

CLASSIFICATION OF COALS BY RANK[1]

ASTM Designation: D 388 - 38

ADOPTED, 1937; REVISED, 1938.[2]

Reapproved in 1961 Without Change.

SPECIFICATIONS FOR CLASSIFICATION OF COALS BY RANK (D 388)

TABLE I.—CLASSIFICATION OF COALS BY RANK.[a]

Legend: FC = Fixed Carbon VM = Volatile Matter Btu = British thermal units

Class	Group	Limits of Fixed Carbon or Btu Mineral-Matter-Free Basis	Requisite Physical Properties
I. Anthracitic	1. Meta-anthracite	*Dry* FC, 98 per cent or more (Dry VM, 2 per cent or less)	
	2. Anthracite	Dry FC, 92 per cent or more and less than 98 per cent (Dry VM, 8 per cent or less and more than 2 per cent)	
	3. Semianthracite	Dry FC, 86 per cent or more and less than 92 per cent (Dry VM, 14 per cent or less and more than 8 per cent)	Nonagglomerating[b]
II. Bituminous[d]	1. Low volatile bituminous coal	Dry FC, 78 per cent or more and less than 86 per cent (Dry VM, 22 per cent or less and more than 14 per cent)	
	2. Medium volatile bituminous coal	Dry FC, 69 per cent or more and less than 78 per cent (Dry VM, 31 per cent or less and more than 22 per cent)	
	3. High volatile *A* bituminous coal	Dry FC, less than 69 per cent (Dry VM, more than 31 per cent); and moist[c] Btu, 14,000[e] or more	
	4. High volatile *B* bituminous coal	Moist[c] Btu, 13,000 or more and less than 14,000[e]	
	5. High volatile *C* bituminous coal	Moist Btu, 11,000 or more and less than 13,000[e]	Either agglomerating or nonweathering[f]
III. Subbituminous	1. Subbituminous *A* coal	Moist Btu, 11,000 or more and less than 13,000[e]	Both weathering and nonagglomerating
	2. Subbituminous *B* coal	Moist Btu, 9500 or more and less than 11,000[e]	
	3. Subbituminous *C* coal	Moist Btu, 8300 or more and less than 9500[e]	
IV. Lignitic	1. Lignite	Moist Btu, less than 8300	Consolidated
	2. Brown coal	Moist Btu, less than 8300	Unconsolidated

[a] This classification does not include a few coals which have unusual physical and chemical properties and which come within the limits of fixed carbon or Btu of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 per cent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free Btu.

[b] If agglomerating, classify in low-volatile group of the bituminous class.

[c] Moist Btu refers to coal containing its natural bed moisture but not including visible water on the surface of the coal.

[d] It is recognized that there may be noncoking varieties in each group of the bituminous class.

[e] Coals having 69 per cent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of Btu.

[f] *There are three varieties of coal in the high-volatile C bituminous coal group, namely:* Variety 1, agglomerating and nonweathering; Variety 2, agglomerating and weathering; Variety 3, nonagglomerating and nonweathering.

SELECTION OF COALS FOR COKING[1]

Approximately 16 per cent of the bituminous coal in the United States is converted into coke. In the early days of the coke industry, high-grade coking coals were plentiful, but reserves of these coals are gradually giving out, with the result that the less desirable grades must be used. Sulphur and ash contents have gradually increased through recent years, and there is much activity to find and develop new coals suitable for coking. The blending of two or more coals has made enormous coal reserves available for coking.

Sources of Coking Coal.[2] According to the U.S. Bureau of Mines[2] the great source of coking coal has been the Appalachian region, extending from Pennsylvania to Alabama. States in this region supplied more than 96 per cent of all coal purchased in 1946 for oven coke. In order of tonnages, the ranking states which shipped coal to oven-coke plants were Pennsylvania and West Virginia, each furnishing 36 per cent of the total; Kentucky 14 per cent; Alabama 8 per cent; and Virginia and Tennessee combined 2 per cent. Other states that supplied significant tonnages of coking coal were Utah and Colorado, which together furnished 2 per cent of the total. The best high-, medium-, and low-volatile coking coals are found in West Virginia, eastern Kentucky, western Virginia, Pennsylvania, and Alabama. The low-volatile coking coals, such as are very important for improving the physical properties of metallurgical coke, especially its strength, come mostly form West Virginia and, to a lesser extent, from central Pennsylvania, western Virginia, Oklahoma, and Arkansas.

The expansion of the steel industry in the Far West during the Second World War focused attention on the supply of coking coal from that area. The present source of coking coal for the steel plants in Utah and California is the Sunnyside bed of Utah. Through exploration, the U.S. Bureau of Mines has discovered additional reserves of coking coal near Kemmerer, in southwestern Wyoming, and in Gunnison County, Colorado.

Coke-plant operators reported to the Bureau of Mines that 59 per cent of all coal purchased for the manufacture of oven coke in 1946 was obtained from captive mines.

Effect of Coal Properties on Coking.[3] The suitability of a coal for producing coke depends upon many properties and characteristics, several of which are very difficult to evaluate without actual trial in an oven. Volatile matter, ash, and sulphur content are among these many factors of primary importance.

Volatile Content. Coals of very high volatile content result in coke of relatively low strength, and they are thus usually used in a blend with low-volatile coals. Low-volatile coals have a tendency to expand when heated and yield somewhat lower quantities of coal chemicals or by-products.

Volatile matter should fall between 28 and 35 per cent in coal on a dry ash-free basis. Coals of higher volatile content are often used but at the expense of the strength of the coke.

Ash. Ash in the coal is of course carried over into the coke. Ash content of coke is about 1.35 times that of the coal charged to the oven. High-ash coal is said to reduce iron production by about 5 per cent for each per cent of ash.

Low ash is desirable, the lower the better, and with not over 10 per cent if at all possible.

Sulphur. Between 60 and 70 per cent (usually 62 per cent) of the sulphur in the coal remains in the coke. It should therefore be as low as possible, preferably not over 1.2 per cent for coke for blast-furnace use, and 1.0 per cent for coke for foundry use.

Moisture. Excessive moisture in the coal may injure the oven brickwork. Seven per cent may be considered a maximum.

Oxygen Content. Coke of best quality is made from coals of relatively low oxygen content. More than 8 per cent oxygen on a dry ash-free basis will not make good commercial coke, although higher oxygen coal is used in some cases. Some authorities state that a hydrogen-oxygen ratio of 0.6 or more is desirable, with 0.55 a minimum value.

Expansion on Heating. During the coking process, coals may undergo marked changes in volume. Some coals may expand while others contract, and there is no sure way to predict exactly which way a coal will behave except by actual test.

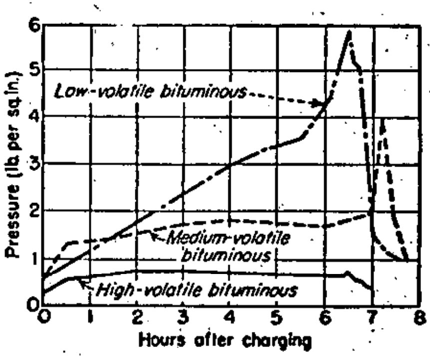


Fig. 6-5. Pressures developed by three typical coals during coking process. (*Ess, Iron and Steel Engineer*, 1948.)

[1] Ess, T. J., *Iron Steel Engr.*, pp. C5–C7.
[2] "Minerals Yearbook," U.S. Bureau of Mines (available through Superintendent of Documents), preprint p. 24, 1946.
[3] Ess, T. J., *Iron Steel Engr.* See also The Practical Effect of Various Properties of Coal, p. 35.

2

In general, low-volatile coals expand and high-volatile coals contract, even though the coals come from the same seam. Tests of coals from the lower Kittanning seam show 40 per cent or more expansion with 17 to 18 per cent volatile matter, and 27 to 30 per cent contraction with 42 per cent volatile. At approximately 31 per cent volatile, there seems to be no volume change. Similar tests on No. 3 Pocahontas seam shows 20 per cent expansion with 17 per cent volatile matter and 3 per cent expansion with 24 per cent volatile. (All volatile contents in these tests are reported on the dry ash-free basis.)

Since expanding coals may exert dangerous pressures against the oven walls, it is necessary that such coals be used in blends with coals that contract while coking so that the final mixture is approximately neutral. Even then care must be exercised not to vary coking practice, as mixtures which may be safe when coked for long times at low temperatures may be dangerous at faster coking rates with higher temperatures. Likewise, the expansion of a coal or a coal mixture will increase if the bulk density of the charge increases. Finer pulverization and increased moisture (up to 7 per cent) tend to reduce density and hence reduce expansion during coking. See also Plastic Properties of Bituminous Coals, page 93.

Pressures Developed by Coals. According to Ess,[1] pressures developed by bituminous coals may range somewhat as follows:

High-volatile Bituminous. From ½ to ⅔ psi, remaining more or less constant through the coking process.

Medium-volatile Bituminous. From ½ psi at charging to 1¾ psi after ½ hr, and then remaining rather constant except for a sudden peak of 4 psi at 7 hr.

Low-volatile Bituminous. From ½ psi at charging up to 6 psi at 6½ hr. The occurrence of pressure peaks in an otherwise uniform pressure record shows that ovens may be damaged, even though badly sticking ovens are not encountered in pushing.

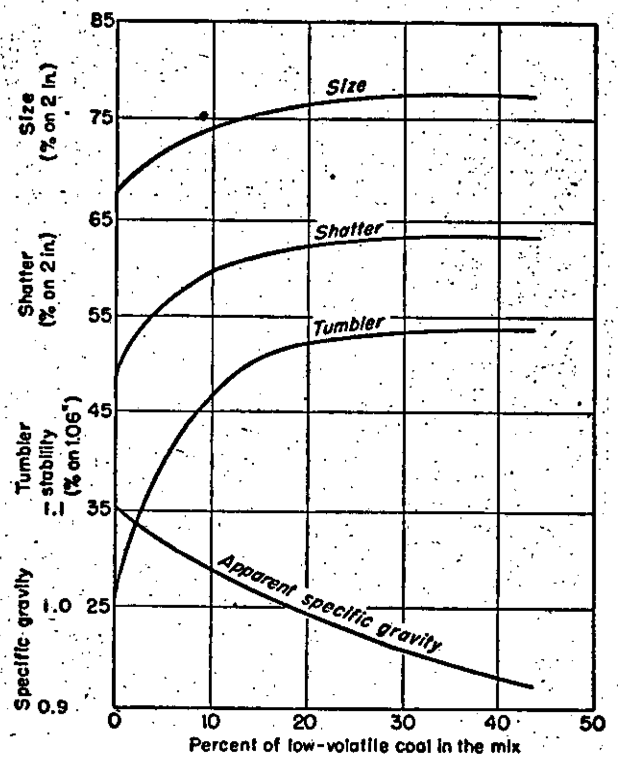


FIG. 6-6. Variations in physical properties of coke with varying proportions of low-volatile coal in the mix. (*Ess, Iron and Steel Engineer*, 1948.)

These pressure characteristics of the several very general types of coal are also shown as Fig. 6-9.

Size Consist. The sizing of the raw coal affects coke quality to a considerable extent. Harder coke is obtained from pulverization to 70 per cent through ⅛-in. mesh than if pulverized to 50 per cent through ⅛-in. There is considerable variation in the degree of pulverization through the industry, depending principally on local conditions and the use for which the coke is primarily intended. In general, operators seem to favor pulverization so that 80 to 90 per cent passes through ⅛-in.-mesh screen, particularly if the blending of two or more coals is being employed. A high degree of pulverization results in less segregation and a more intimate mixture,

[1] Ess, T. J., *Iron Steel Engr.*

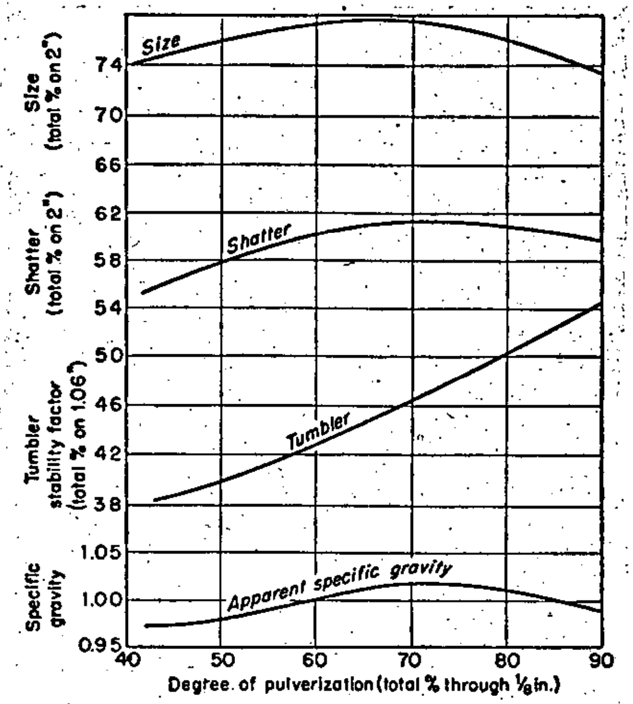


FIG. 6-7. Effect of degree of pulverization of coal on physical properties of resultant coke. (*Ess, Iron and Steel Engineer*, 1948.)

although it also gives lower bulk density, and, if the mixture contains too much very fine coal, coke quality suffers. Some operators believe that fine crushing of the coal results in higher coal-chemical (by-product) yield. In some cases, where only high-volatile coals are used, and even where mixtures of coal are used, coarse coal (up to 1½ in.) is used to obtain high bulk density. The best size of pulverized coal must be determined by the individual plants for each coal or blend used.

Table 6-15. Typical Analyses of By-product Coke from Various Coals[1]

Kind of coal	Per cent by weight									
	Water	Volatile	Fixed C	Ash	S	P	SiO_2	Al_2O_3	Bases	Fe
Connellsville, Pa.	0.32	1.70	86.50	11.50	0.75	0.020	5.30	3.00	4.30	2.60
Pocahontas, W. Va.	....	2.31	90.62	6.97	0.70					
New River, W. Va.	....	2.82	90.52	6.36	0.70					
Davis, W. Va.	0.33	1.20	87.97	10.50	0.55	0.034	4.27	3.89	....	1.40
Derry, Pa.	....	2.50	81.60	14.70	1.20					
Webster, Pa.	....	1.10	88.40	10.50	0.95	0.030	4.80	3.50	....	1.85
Klondike, Pa.	....	2.50	84.50	12.00	1.00					
Loyalhanna, Pa.	....	2.45	81.20	15.00	1.35					
Mountain, Pa.	0.50	1.10	85.85	11.53	1.00	0.018				
Fairmont, W. Va.	0.30	0.97	87.43	11.30	1.35	0.020	4.16	2.53	....	2.45

[1] *Iron Steel Engr.*

Bulk Density. Control of bulk density of the coal charged to the ovens has recently received considerable attention. Such control results in coke with more uniform physical characteristics and also simplifies heating and operation of the ovens. The principal factor affecting bulk density is the surface moisture of the coal, although fineness of crushing is also important. Bulk density decreases as surface moisture increases and as coal fineness increases. The effect of moisture content can be offset to a great extent by the addition of small amounts of oil to the coal charge. Such additions increase the bulk density of wet coal but may reduce somewhat the bulk density of coal that has no surface moisture. Results from tests in one plant showed that the addition of 1 gal of oil per ton of coal resulted in a 7 per cent increase in bulk density and that the use of oil decreased the fluctuations in density caused by changes in moisture content of coal.

Coke Yield as Affected by Coal Properties[1]

Coke yields as obtained from various coals are closely proportionate to the rank of the coal as measured by its fixed carbon, running 102 to 113 per cent of the fixed carbon plus ash content of the coal as carbonized. The coke yield is greater than the fixed carbon plus ash contents because of the deposition of carbon by thermal decomposition of hydrocarbons in gases and vapors passing through the coke mass. When coke yields (dry) are plotted against fixed carbon plus ash, a straight line develops, the formula being

$$\text{Per cent coke yield, dry} = 19 + 0.79(C + A)$$

where C = per cent of fixed carbon in the coal
A = per cent of ash in the coal

The ash content of the coke, which equals the ash content of the coal divided by the coke yield, may therefore be expressed as

$$\text{Per cent of ash in dry coke} = \frac{100A}{19 + 0.79(C + A)}$$

with symbols as in the preceding equation.

Coke yield drops as the carbonizing temperature is increased up to about 1650°F, because of the more complete driving off of the volatile matter, which reaches a minimum of about one-half at this temperature. The carbon content of the coke increases, and the Btu per pound of coke decreases simultaneously. Above 1650°F, the coke yield increases slightly because of carbon deposition.

Relation of Coke Characteristics to Rank of Coal

According to Perch and Russell,[2] there is sufficient evidence from past experience to indicate that characteristics of coke produced from a given coal are in some measure related to the rank of coal. Broadly speaking, the high-volatile C bituminous coals make very small fragile cokes, if the coals coke at all; whereas the high-volatile A coals produce much better cokes. Although the low-volatile coals produce strong cokes, they cannot be carbonized unblended in by-product ovens because of their pressure characteristics.

After a careful effort to use some interpretation of the standard method of classifying coal as a prediction of the coking properties, the authors concluded that a modification was necessary to express results properly. They thus devised a chart in which

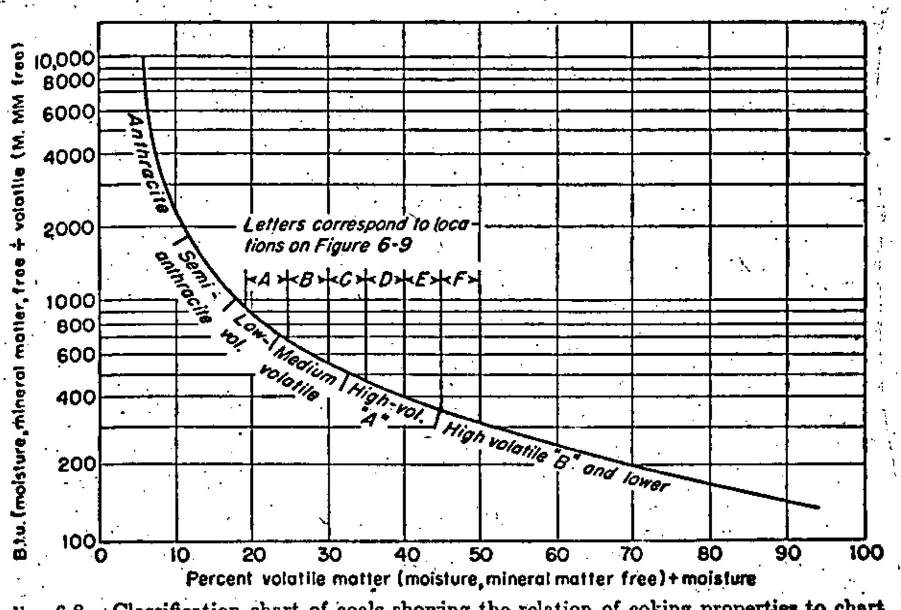


Fig. 6-8. Classification chart of coals showing the relation of coking properties to chart location. (*Based upon Perch and Russell, Mining Engineering, June, 1949.*)

[1] Ess, T. J., *Iron Steel Engr.* pp. C30, C31.
[2] Perch, Michael, and Charles C. Russell, A Study of Coal Classification and Its Application to the Coking Properties of Coal, *Mining Eng., AIME*, June 1949, p. 205.

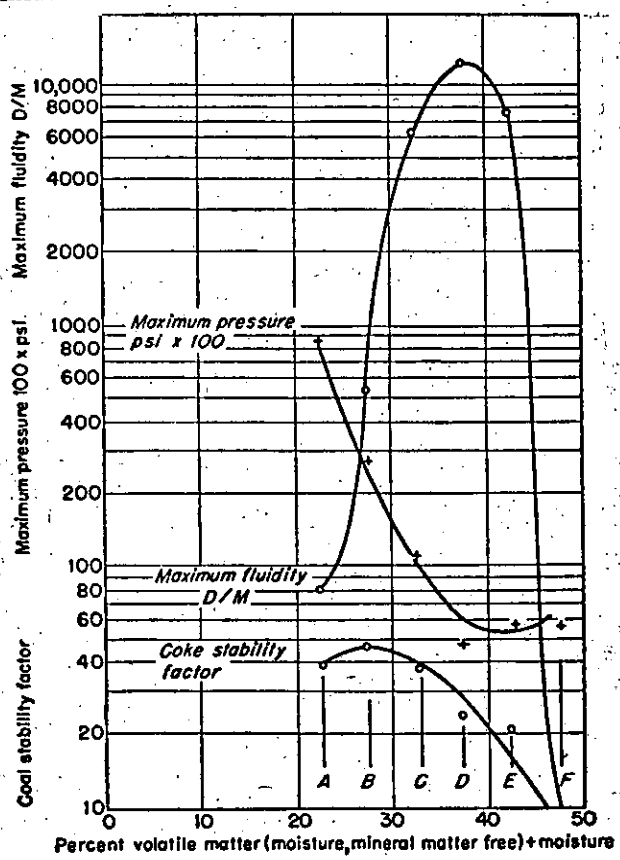


FIG. 6-9. Relation between coking properties of coals and volatile $+H_2O$.

the ratio of the heating value of the coal to percentage of volatile matter is plotted as the ordinate on a logarithmic scale and dry volatile matter plus moisture is plotted as the abcissa on an arithmetric scale. Both are on a mineral-matter-free basis. In the resultant chart, all ranks of coal (except anthracite) fell practically on the curve.

A general examination of this classification scheme revealed that the coals appeared to be aligned in order of their determined coking behavior. Figure 6-8 shows this curve, on which are also shown the *very approximate* divisions between the major ranks of coal.

Superimposing some 36 coals of known coking behavior on this modified classification curve, the authors found that all fell within the range marked *A* to *F* on Fig. 6-8. A further analysis of this imposition shows that, for each segment of the curve, marked *A* to *F*, plottable points are available for pressure, fluidity, and stability. These are shown as Fig. 6-9. While the authors referred to the curve for a location of individual coals, if all points fall on the curve as stated, only the abcissa, or per cent volatile moisture, as used in Fig. 6-8, is needed to establish a relationship between coal characteristics and coking properties. (It should be noted that this is a very new, relatively unproved relationship. However, in view of the paucity of technical guides as to the suitability of coals for coking, it is presented with this reservation, and with considerable modification by the editors.)

Table 6-16. Relation between Volatile + Moisture, and Coking Characteristics[1]

Location on Figs. 6-8 and 6-9	Volatile + moisture[a]	No. of analyses	Max fluidity, *D/M*	Max pressure, psi	Coke stability factor	Per cent ash in coal
A	19–25	6	76	8.06	40	4.7–13
B	25–30	2	530	2.57	48	5.1–18
C	30–35	5	6,370	1.07	39	3.6–26
D	35–40	7	11,570	0.48	24	4.7–7.7
E	40–45	9	7,335	0.59	22	3.5–15
F	45–50	7	7	0.58	6	3.1–20

[1] PERCH, MICHAEL, and CHARLES C. RUSSELL, *Mining Eng., AIME*, June, 1949, p. 205.

[a] Volatile is moisture- and mineral-matter-free. See Figs. 6-8 and 6-9 for graphic presentation of this material.

BLENDING COALS FOR COKING[1]

In 1946, 72 of the 85 active plants in the United States carbonized coal of different volatile content. High- and low-volatile coals were blended by 46 plants; high-, medium-, and low-volatile by 3 plants; and high- and medium-volatile by 3 plants. Of the plants that carbonized straight or unblended coals, 10 used straight high-volatile and 3 medium-volatile. At plants where blending is practiced, the proportion of the different kinds of coal mixed before charging into ovens varies widely from plant to plant according to local conditions. A classification of all coal purchased for coking in vertical slot-type ovens in 1946 indicated, however, that 66 per cent was high-volatile, 13 per cent medium-volatile, and 21 per cent low-volatile.

While exact performance depends upon local conditions, on a basis of tests in which 100-lb samples were carbonized in a horizontal steel retort, Mendelshon[2] reports that the yield resulting from the blending of bituminous coals may be predicted from the following equation:

$$\text{Per cent coke yield} = \tfrac{1}{100}[ax + (100a)y]$$

where a = per cent of one coal in the blend
x = per cent of coke produced from this coal
y = per cent of coke produced from the other coal

The agreement between this equation and actual test results published by the Bureau of Mines is said to be excellent.

[1] "Minerals Yearbook," U.S. Bureau of Mines, preprint 1946, p. 24.
[2] MENDELSHON, J., *Fuel*, vol. 13, No. 5, pp. 140–154, 1934, as quoted by *Penn. State Coll. Mineral Inds. Expt. Sta. Cir.* 16, p. 10.

Anthracite Fines in Coke Production[1]

Since 1942, there has been a progressive increase in the use of anthracite fines in mixture with high- and low-volatile bituminous coals for feed stock in the production of blast-furnace and foundry coke. The material is considered an inert, which appears to permit the use of higher flue temperatures and shorter coking time and thus increases the throughput.

In general, the following characteristics are of importance in selecting anthracite fines for use in blends:

1. Particle size
2. Size consist (size distribution)
3. Density, volatile content, and sulphur
4. Ash content

No. 5 buckwheat anthracite specification is considered the best suited for blending use, although there is presently an interest in the flotation anthracite at some plants.

In general, the size consist most desired is

Mesh	*Max Per Cent*
10	5
10–20	20
20–40	60
40–100	10
100	5

Volatile-matter content is generally limited to 6 per cent maximum. True specific gravity is approximately 1.70 with 50 per cent sink in carbon tetrachloride. Low ash content.[2]

Use of Anthracite Fines in By-product Coke Blends[3]

Clendenin, Barclay, and Wright report the technical aspects of blending anthracite fines with bituminous coals for making by-product coke in considerable detail, with emphasis on the several factors influencing the quality and yield of the products.

They conclude that, up to at least 10 per cent anthracite addition, the properties of the resultant coke appear to be entirely satisfactory for non-blast-furnace uses, such as for foundries, water-gas generators, and domestic fuel. On the other hand, cokes produced from blends containing small percentages of anthracite fines are not, as yet, generally acceptable for modern blast-furnace use. It is claimed by some operators that anthracite-blend cokes possess a deficiency in certain desirable strength characteristics which is reflected in a disturbance in the blast-furnace operating cycle. Recently, however, at least one blast furnace reported favorably on the use of 5 per cent anthracite in their coking blend, and several other plants are reported as trying the use of 2½ to 3 per cent blends. In the non-blast-furnace field, several different

[1] KERRICK, J. H., research engineer, The Philadelphia & Reading Coal & Iron Co., Philadelphia, Pa.
[2] For further technical information, refer to *Penn. State Coll. Mineral Inds. Expt. Sta. Circ.* 16 and *Tech. Paper* 136.
[3] CLENDENIN, J. D., K. M. BARCLAY, and C. C. WRIGHT, The Technical and Economic Aspects of the Use of Anthracite Fines in By-product Coke Production, *Penn. State Coll. Bull., Mineral Indus. Expt. Sta. Circ.* 10, 1944.

plants are known to be using about 5 per cent No. 5 buckwheat anthracite in their coking blends, and a number of foundries are now operating on such cokes.

For carbonization in regular by-product ovens, the use of more than 20 per cent anthracite in the blend has not proved feasible for the production of coke. Additions of anthracite in excess of about 10 per cent affect the size distribution and physical properties of the coke adversely. Maximum upgrading in shatter index of the coke is reached at about 10 per cent anthracite, while the tumbler-test stability and hardness factors appear to show slight but progressive decreases with increasing additions of anthracite.

Yield. The use of several per cent of anthracite will permit a reduction in the coking time and consequently an increase in throughput, conservatively estimated to amount to at least 10 per cent. The increased throughput will vary with particular conditions, and there is no evidence to indicate that increasing the percentage of anthracite will permit further reductions in the coking time. Within the admixture range of 0 to 10 per cent anthracite, the yield of coke has been found to increase approximately 0.1 per cent for each per cent of anthracite added to the blend.

Effect on Gas Yield. The yield and heating value of the gas from the carbonization of anthracite is less than that from an equal weight of bituminous coal. For low- and medium-volatile anthracites the yield and thermal value of the gas may be expected to average about 5.3 million cu ft and 1.8 million Btu respectively, per ton of coal. Additions of anthracite to bituminous coal will therefore reduce both the yield and quality of the gas per unit weight of blend carbonized. The reduction in volume per unit weight of blend carbonized is about 0.5 per cent for each per cent of anthracite added, while the reduction in thermal value is about 0.6 to 0.7 per cent for each per cent of anthracite added. Because of the increased throughput, however, the use of anthracite permits an increase in the daily gas production. Calculated to an equivalent heating value, the increased daily gas production may reach as much as 5 to 6 per cent. Additions of anthracite greater than 11 per cent result in a decreased yield of gas on both the daily and the per ton of coal or coke basis.

Effect on By-products. Available data suggest that anthracite has no residual value for the production of by-products other than gas and may be considered as an inert diluent. The by-product yield per ton of blend carbonized is therefore inversely proportional to the percentage of anthracite used in the blend. As with gas yield, however, the increased throughput counteracts the decrease in unit weight, and increases in the daily by-product yield up to about 5 per cent should be possible with the smaller percentages of anthracite. Addition of anthracite in excess of 8 per cent will probably result in a decrease in daily yield as well as the yield per ton of coal or coke.

Advantages and Disadvantages of Blending Anthracite[1]

Clendenin and Kohlberg list and discuss the following reasons for and against blending anthracite with bituminous coal for the manufacture of coke:

Reasons for Blending Anthracite

1. With proper blending, there is an increase in the percentage yield of foundry-sized coke.
2. Increased daily yield of foundry coke by use of higher flue temperatures and shorter coking times is feasible.
3. Small increase in percentage yield of total coke is noted.
4. Coke strength and hardness as measured by the shatter test are increased.
5. Greater uniformity of coke size is obtained.
6. There is an additional source of available coal.
7. No additional pulverizing and screening equipment is needed.
8. Possibly, more rapid heat transfer in oven charge is induced.
9. Relief from excess oven pressure of low-volatile coals in mix can be secured by substitution of fine anthracite for part of the low-volatile coal.
10. Some evidence suggests that substantial proportions of certain Illinois coals can be used in four- and five-component blends with fine anthracites to produce suitable cokes.
11. Tests and experiments indicate that, in addition to the importance of superficial surface of the additive in blending, intrinsic (surface) properties of fine anthracites may be a significant factor.

[1] Clendenin, J. D., and Joseph Kohlberg, The Blending of Anthrafines in Coke Production. *Penn. State Coll. Tech. Paper* 136, 1948.

Reasons against Blending Anthracite. In listing potential disadvantages of blending anthracite fines, Clendenin and Kohlberg[1] carefully refer to them as "those most commonly put forth" as distinguished from their having been developed in the investigation at hand. Nevertheless, the following do represent the opinion of many coke-plant operators as to possible disadvantages:

1. The yield of gas and coal chemicals—tar, light oil, and ammonia—is decreased when fine anthracites are used.
2. The yield of coke breeze is increased.
3. The abrasion strength or hardness of the coke as measured in the tumbler test is usually decreased.
4. The ash content of the coke may be or is assumed to be increased.
5. Additional coal-handling problems arise, including those with wet and frozen fines; windage losses increase; and an additional bin and extra equipment are needed for the additional component.
6. Possible alteration of the cell structure of the coke and changes in coke porosity may occur.
7. Yield of salable coke is decreased when coke must be crushed for production of smaller sizes.

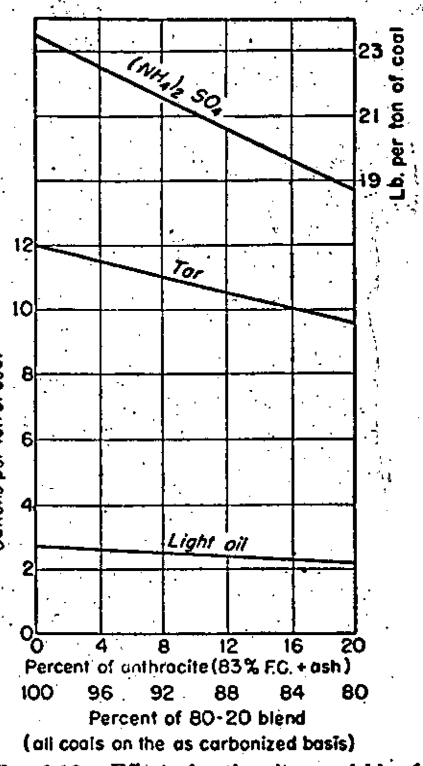


FIG. 6-10. Effect of anthracite on yields of by-products from a blend of 80 per cent Powellton and 20 per cent Pocahontas No. 4. (*Clendenin, Barclay, and Wright.*)

Similarly, as with reasons in favor of blending the fine sizes of anthracite, most of these may be applied with equal force to the blending of coke breeze.

Clendenin and Kohlberg[1] discuss these reasons against blending in some detail; and, though the following are not quotes, they may be said to summarize their findings: (1) It is admitted that anthracite has no residual value with respect to tar, ammonia, and light oil, but the net decrease in yields is very slight where small proportions of anthracite are used. (2) The increase in breeze yield is probably true, but it is felt that it can be controlled by careful anthracite selection, pulverization, blending, etc. (3) The strength and hardness are affected by blending but can undoubtedly be influenced by care in mixing, experience in blending, and other factors that will be gained by continued experience. (4) Increase in ash content is felt to be more apparent than real, since it may be in the order of only about $\frac{1}{10}$ of 1 per cent. (5) Handling problems depend entirely on local plant conditions. (6) Charges that anthracite has a deleterious effect on cell structure would seem to be without serious basis in fact. (7) Decreased yield of salable coke where crushing is practiced is a real objection but has no bearing where crushing is not needed.

Type of Anthracite Suited. The proper selection of a suitable anthracite is an important consideration. The use of anthracites of a soft, friable, or decrepitating nature is to be avoided. A hard anthracite, free from undesirable friability and decrepitation, should be used.

Although anthracite fines may contain a high percentage of ash, the preparation of No. 5 buckwheat size generally produces a product which is suitable for blending purposes; and, where the percentage of anthracite does not exceed about 10 per cent, no marked increase in the ash content of the coke is produced. Replacing a bituminous-coal blend, which produces coke containing from 5 to 8 per cent ash, with anthracite containing 83 per cent fixed carbon plus ash, will, for each per cent of anthracite replacing the bituminous-coal blend, result in the following increases in the ash content of the resultant coke:

Per Cent Ash in Anthracite	*Per Cent Increase in Ash per 1 Per Cent Anthracite Used*
10	0.06
15	0.14
20	0.20

[1] *Loc. cit.*

The ash content of coke made from coal blends of bituminous and anthracite is expressed more flexibly in the following equation:

$$\text{Per cent ash in coke} = \frac{(A \times a) + (B \times b) + (C \times c)}{(A \times X) + (B \times Y) + (C \times Z)}$$

where A, B, and C refer to the percentages of the component coals used in the coking blend
a, b, and c refer to the ash contents of the original coals
X, Y, and Z refer to the percentages of coke from the component coals when coked individually

Impurities. No difficulty should be experienced with the sulphur and phosphorus in anthracite, because these elements are present in amounts smaller that those usually found in bituminous coking coals. Since the ash-fusion temperature of anthracite ash is usually high, no trouble is likely to be encountered.

Sizing. Recently it has been shown that anthracite fines of No. 5 buckwheat size (approximately 20 by 100 mesh), will produce a satisfactory blend for foundry and, possibly, blast-furnace use. It is essential that oversize anthracite particles be absent, since they tend to cause points of weakness in the coke.

Thorough Mixing Essential. One of the principal causes of poor results in the carbonization of mixtures of anthracite fines and coking bituminous coals is the failure to mix the component fuels intimately. The anthracite particles must be thoroughly dispersed throughout the bituminous coal if satisfactory agglomeration of the mass is to be obtained. Segregation of anthracite frequently produces localized weaknesses in the coke.

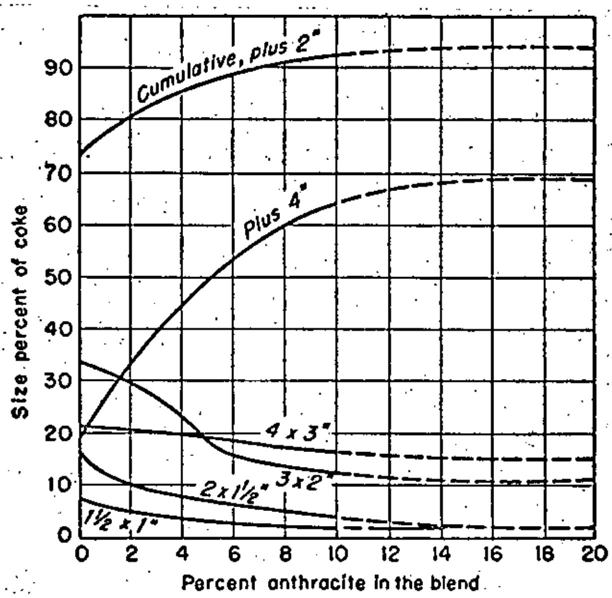
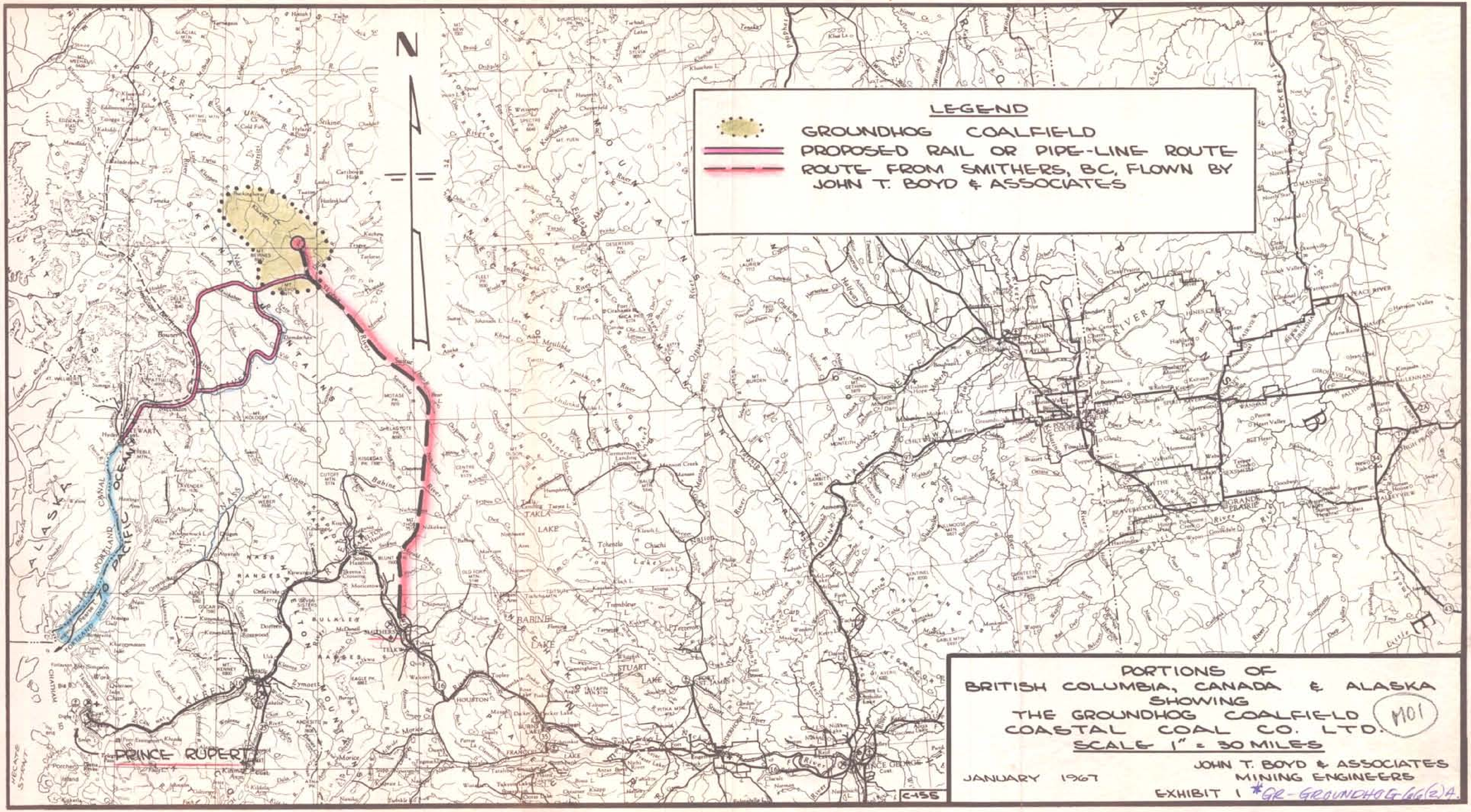


FIG. 6-11. Relation between per cent of anthracite in blend and size distribution of the coke. (*Clendenin, Barclay, and Wright.*)

Table 6-17. Effect of Anthracite on Physical and Chemical Properties of Coke[1]

Test No.	I	II	III
Blend, per cent:			
High-volatile bituminous	75	75	80
Low-volatile bituminous	25	20	15
Anthracite	0	5	5
Coal blend analyses:			
Moisture, per cent	4.1	4.6	4.6
Volatile, per cent	29.4	28.1	28.4
Ash, per cent	7.2	7.5	7.7
Sulphur, per cent	0.63	0.57	0.61
Analyses of coke:			
Volatile, per cent	0.3	0.4	0.3
Ash, per cent	8.9	9.0	8.8
Sulphur, per cent	0.52	0.48	0.49
Screen test (run of oven):			
On 3½-in., per cent	28.0	55.6	45.1
On 3-in., per cent	49.0	72.2	60.8
Sp gr of coke:			
Apparent	0.94	1.01	0.98
True	1.91	1.83	1.87
Porosity, per cent	51.1	45.3	47.8
Shatter index (foundry size) cumulative per cent on 2 in.	74.2	89.0	84.0

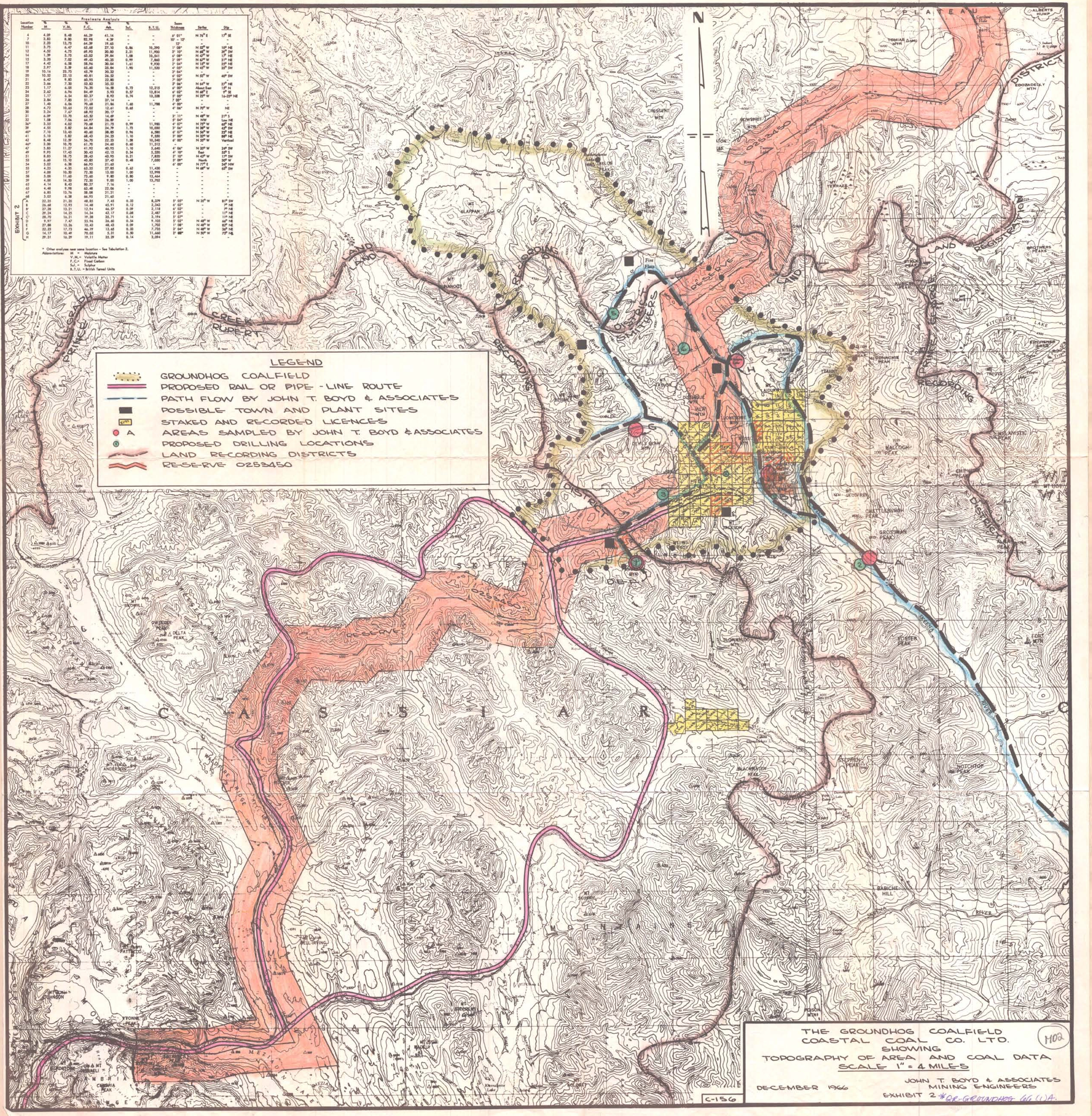
[1] CLENDENIN, BARCLAY, and WRIGHT, *loc. cit.*
The coking time reported in each of these tests was 16.8 hr, in 17-in. ovens.


LEGEND
GROUNDHOG COALFIELD
PROPOSED RAIL OR PIPE-LINE ROUTE
ROUTE FROM SMITHERS, BC, FLOWN BY JOHN T. BOYD & ASSOCIATES
N
PRINCE RUPERT
SMITHERS
PRINCE GEORGE
HOUSTON
TAKLA LAKE
BABINE LAKE
STUART LAKE
GRANDE PRAIRIE
PEACE RIVER
PACIFIC OCEAN
ALASKA
PORTIONS OF
BRITISH COLUMBIA, CANADA & ALASKA
SHOWING
THE GROUNDHOG COALFIELD
COASTAL COAL CO. LTD.
SCALE 1" = 30 MILES
M01
JANUARY 1967
JOHN T. BOYD & ASSOCIATES
MINING ENGINEERS
EXHIBIT 1
*GR-GROUNDHOG-66(2)A.
C-155

Location Number	% M	% V.M.	% F.C.	% Ash	% Sul.	B.T.U.	Seam Thickness	Strike	Dip
	Proximate Analysis								
4	4.09	8.48	46.29	41.14	-	-	6' 01"	N 76° E	17° SE
7	3.83	8.80	82.98	4.39	-	-	10' - 12'	-	-
10	2.23	13.73	64.39	19.65	-	-	12'	-	-
11	3.75	6.47	62.68	27.10	0.86	10,290	1' 08"	N 52° W	10° NE
12	4.52	4.75	69.93	20.80	2.31	11,900	3' 10"	N 68° W	39° SW
14	1.39	5.75	63.02	29.84	1.08	10,541	6' 08"	N 47° W	17° NE
15	3.20	7.02	49.43	40.35	0.99	7,860	3' 09"	N 67° W	31° NE
17	4.42	6.58	58.96	30.04	1.61	9,930	2' 04"	N 15° W	25° NE
18	2.97	5.59	65.60	25.84	1.90	11,520	4' 05"	N 45° W	35° SW
19	10.16	23.73	45.79	20.32	-	-	3' 04"	-	-
20	10.52	22.15	40.81	26.52	-	-	6' 02"	N 53° W	40° SW
21	6.42	9.83	60.95	22.80	-	-	7' 00"	-	-
22	3.66	7.30	53.82	35.22	-	-	3' 06"	N 64° W	27° NE
23	1.17	6.05	76.20	16.58	0.72	12,215	6' 00"	About East	15° N
24	2.62	6.96	84.49	5.93	0.57	13,814	6' 02"	N 68° E	9° SE
25	1.17	6.54	83.37	8.92	0.74	13,328	5' 05"	N 22° W	16-22° NE
26	3.84	7.85	51.17	37.14	-	-	7' 00"	-	-
27	1.40	6.06	70.68	21.86	1.60	11,788	4' 00"	-	-
28	4.72	10.65	72.02	12.61	0.65	-	4' 06"	N 70° W	NE
30	3.24	7.67	68.92	20.17	-	-	-	-	-
31	6.09	13.70	65.52	14.69	-	-	3' 11"	N 48° W	21° S
32	1.08	7.06	64.97	26.89	-	-	5' 04"	NW	Low NE
36*	3.55	4.02	70.68	21.75	0.99	11,980	4' 07"	N 75° W	65° NE
39	4.55	5.82	64.84	24.79	1.73	10,030	3' 06"	N 38° W	45° SW
40*	7.10	13.45	40.60	38.85	0.96	6,580	6' 07"	N 56° W	23° NE
41	5.10	5.82	68.43	24.25	1.10	9,550	3' 00"	N 32° W	88° NE
42	8.48	12.59	56.70	22.23	1.58	10,340	6' 00"	N 55° W	Vertical
46*	3.00	10.70	61.70	24.60	0.60	11,312	-	-	-
47	5.85	11.27	41.92	40.95	1.10	5,640	4' 06"	N 35° W	24° SW
49	9.95	17.45	30.45	42.15	0.34	5,320	4' 10"	East	55° S
51	8.85	18.75	28.45	43.95	0.21	7,820	2' 10"	N 43° W	17° SW
53	6.60	15.10	40.85	37.45	0.48	7,050	3' 09"	North	30° W
54	5.02	6.38	66.95	21.65	-	-	6' 00"	N 77° E	34° NW
55	4.25	4.35	63.55	27.85	0.62	11,430	-	N 68° W	63° SW
57	4.00	10.50	72.50	13.00	1.00	12,998	-	-	-
58	5.00	11.60	73.60	9.80	0.80	13,464	-	-	-
59	4.00	14.50	72.50	9.00	1.00	13,702	-	-	-
62	4.14	8.43	80.27	7.16	-	-	-	-	-
63	4.48	9.98	63.48	22.06	-	-	-	-	-
67	6.85	13.76	58.08	21.31	-	-	-	-	-
68	5.02	6.38	66.95	21.65	-	-	-	-	-
EXHIBIT 2 A	22.35	21.35	48.85	7.45	0.33	8,379	5' 05"	N 35° W	81° SW
B	26.68	12.93	14.48	45.91	0.12	2,343	6' 02"	-	7° NE
B'	27.28	13.21	12.94	46.57	0.09	2,118	6' 02"	-	7° NE
C	29.24	14.25	14.34	42.17	0.08	2,487	5' 07"	-	11° NE
C'	28.70	16.21	19.38	35.71	0.14	3,194	5' 07"	-	11° NE
D	9.97	7.47	55.96	26.60	0.54	9,105	5' 02"	N 48° W	66° NE
E	27.88	13.26	10.43	48.43	0.09	1,702	1' 08"	N 48° W	82° NE
F	22.23	17.73	46.19	13.65	0.33	7,735	3' 04"	N 48° W	36° NE
G	14.17	10.49	70.03	5.31	0.50	11,660	2' 08"	N 50° W	73° NE
H	29.31	16.29	19.11	35.29	0.14	3,094	-	-	-

* Other analyses near same location - See Tabulation 2.

Abbreviations:
M = Moisture
V.M. = Volatile Matter
F.C. = Fixed Carbon
Sul. = Sulphur
B.T.U. = British Termal Units



THE GROUNDHOG COALFIELD
COASTAL COAL CO. LTD.
SHOWING
TOPOGRAPHY OF AREA AND COAL DATA
SCALE 1" = 4 MILES

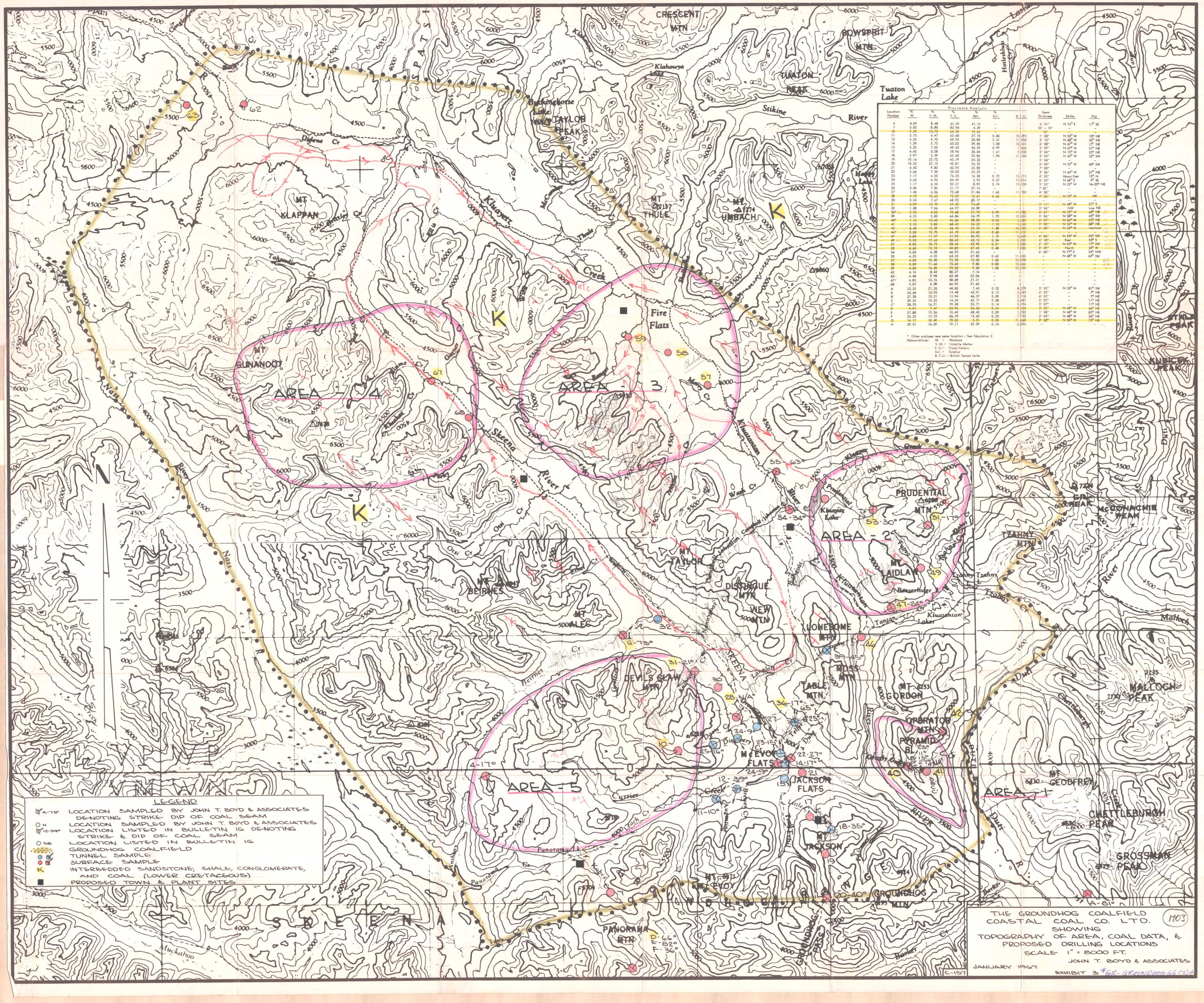
M02

DECEMBER 1966

JOHN T. BOYD & ASSOCIATES
MINING ENGINEERS

EXHIBIT 2 *GR-GROUNDHOG 66 (1)A.

C-156



Location Number	% M	% V.M.	% F.C.	% Ash	% Sul.	B.T.U.	Seam Thickness	Strike	Dip
4	4.09	8.48	46.29	41.14	-	-	6' 01"	N 7o° E	17° SE
7	3.83	8.80	82.98	4.39	-	-	10' - 12'	-	-
10	2.23	13.73	64.39	19.65	-	-	12'	-	-
11	3.75	6.47	62.68	27.10	0.86	10,290	1' 08"	N 52° W	10° NE
12	4.52	4.75	69.93	20.80	2.31	11,900	3' 10"	N 68° W	39° SW
14	1.39	5.75	63.02	29.84	1.08	10,541	6' 08"	N 47° W	17° NE
15	3.20	7.02	49.43	40.35	0.99	7,860	3' 09"	N 67° W	31° NE
17	4.42	6.58	58.96	30.04	1.61	9,930	2' 04"	N 15° W	25° NE
18	2.97	5.59	65.60	25.84	1.90	11,520	4' 05"	N 45° W	35° SW
19	10.16	23.73	45.79	20.32	-	-	3' 04"	-	-
20	10.52	22.15	40.81	26.52	-	-	6' 02"	N 53° W	40° SW
21	6.42	9.83	60.95	22.80	-	-	7' 00"	-	-
22	3.66	7.30	53.82	35.22	-	-	3' 06"	N 64° W	27° NE
23	1.17	6.05	76.20	16.58	0.72	12,215	6' 00"	About East	15° N
24	2.62	6.96	84.49	5.93	0.57	13,814	6' 02"	N 68° E	9° SE
25	1.17	6.54	83.37	8.92	0.74	13,328	5' 05"	N 22° W	16-23° NE
26	3.84	7.85	51.17	37.14	-	-	7 03"	-	-
27	1.40	6.06	70.68	21.86	1.60	11,788	4' 00"	-	-
28	4.72	10.65	72.02	12.61	0.65	-	4' 06"	N 70° W	NE
30	3.24	7.67	68.92	20.17	-	-	-	-	-
31	6.09	13.70	65.52	14.69	-	-	3' 11"	N 48° W	21° S
32	1.08	7.06	64.97	26.89	-	-	5' 04"	NW	Low NE
36*	3.55	4.02	70.68	21.75	0.99	11,980	4' 07"	N 75° W	65° NE
39	4.55	5.82	64.84	24.79	1.73	10,030	3' 06"	N 38° W	45° SW
40*	7.10	13.45	40.60	38.85	0.96	6,580	6' 07"	N 56° W	23° NE
41	5.10	5.82	68.43	24.25	1.10	9,550	3' 00"	N 32° W	88° NE
42	8.48	12.59	56.70	22.23	1.58	10,040	6' 00"	N 55° W	Vertical
46*	3.00	10.70	61.70	24.60	0.60	11,312	-	-	-
47	5.85	11.27	41.92	40.95	1.10	5,640	4' 06"	N 35° W	24° SW
49	9.95	17.45	30.45	42.15	0.34	5,320	4' 10"--	East	55° S
51	8.85	18.75	28.45	43.95	0.21	7,820	2' 10"	N 43° W	17° SW
53	6.60	15.10	40.85	37.45	0.48	7,050	3' 09"	North	30° W
54	5.02	6.38	66.95	21.65	-	-	6' 00"	N 77° E	34° NW
55	4.25	4.35	63.55	27.85	0.62	11,430	-	N 68° W	63° SW
57	4.00	10.50	72.50	13.00	1.00	12,998	-	-	-
58	5.00	11.60	73.60	9.80	0.80	13,464	-	-	-
59	4.00	14.50	72.50	9.00	1.00	13,702	-	-	-
62	4.14	8.43	80.27	7.16	-	-	-	-	-
63	4.48	9.98	63.48	22.06	-	-	-	-	-
67	6.85	13.76	58.08	21.31	-	-	-	-	-
68	5.02	6.38	66.95	21.65	-	-	-	-	-
A	22.35	21.35	48.85	7.45	0.33	8,379	5' 05"	N 35° W	81° SW
B	26.68	12.93	14.48	45.91	0.12	2,043	6' 02"	-	7° NE
B'	27.28	13.21	12.94	46.57	0.09	2,118	6' 02"	-	7° NE
C	29.24	14.25	14.34	42.17	0.08	2,487	5' 07"	-	11° NE
C'	28.70	16.21	19.38	35.71	0.14	3,194	5' 07"	-	11° NE
D	9.97	7.47	55.96	26.60	0.54	9,105	5' 02"	N 48° W	66° NE
E	27.88	13.26	10.43	48.43	0.09	1,702	1' 08"	N 48° W	82° NE
F	22.23	17.73	46.19	13.65	0.33	7,735	3' 04"	N 48° W	36° NE
G	14.17	10.49	70.03	5.31	0.50	11,660	2' 03"	N 50° W	73° NE
H	29.31	16.29	19.11	35.29	0.14	3,094	-	-	-

Proximate Analysis

* Other analyses near same location - See Tabulation 2.

Abbreviations: M = Moisture
V.M. = Volatile Matter
F.C. = Fixed Carbon
Sul. = Sulphur
B.T.U. = British Termal Units