K-FERNIE R-MORRISSEY R.G(1)B

PROGRESS REPORT
CROPCO PROJECT, 1961

JUNE - 1962 -

Part 1

00 296

00296

PROGRESS REPORT

CROPCO PROJECT, 1961

BRITISH COLUMBIA

Land & Exploration

June 1962

Reviewed and Approved:

Ass't Supervisor - Field Exploration

Geological Engineer

Supervisor - Field Exploration

Ass't Manager - Exploration

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (con't)

LIST OF ILLUSTRATIONS

Page

Tables

Photographs

Charts

Maps

Maps
(In Pocket)

PROGRESS REPORT
CROPCO PROJECT, 1961

SUMMARY

Introduction

During 1961, Columbia Iron Mining Company continued investigation of coal lands held under Option with the Crow's Nest Pass Coal Company, Ltd., Fernie, British Columbia. Purchase prices under Options A and B are $10,000,000 and $17,000,000 respectively. The bulk of the exploration work was performed on land held under Option A in order to effect an early evaluation of this basic area.

Organization of the 1961 program was directed by Arthur R. Still, consultant, Prescott, Arizona, and the project was under his supervision until June 9, 1961. After this date, supervision of the project was transferred to Field Exploration, Columbia Iron Mining Company. Active field work began June 1, 1961, and continued throughout the field season, with drilling continuing until May 1, 1962.

Property Description and Ownership

Detailed descriptions of property are given in the 1960 Progress Report. Property outlines are shown on Maps 6C-403 and 6L-160, this report.

History, Development and Production

This section is covered in the 1960 Progress Report.

Geology

Crowsnest coal basin is a structural basin, approximately 35 miles long in a north-south direction by 15 miles wide, wherein the coal-bearing Kootenay formation of Mesozoic age has been preserved from erosion. Highly-deformed older rocks of Paleozoic and Precambrian ages completely surround the basin (see Map 6M-321).

The Kootenay formation consists largely of shales with interbedded sandstones and coals (up to 10 coal beds). The Basal Kootenay sandstone is the only continuous sandstone, and is used as a datum for correlation purposes. Other sandstones in the Kootenay formation tend to be lenticular, and have limited use in correlation. The Basal Elk conglomerate, the base of which is mapped as the upper contact of the Kootenay formation, is in reality several lenticular beds.

The measured thickness of the Kootenay formation varies from about 1,400 to 2,200 feet in thickness, and averages about 2,000 feet. Coal measures crop out continuously along the west side of the basin, and dip eastward from 15 to 80 degrees. This relationship allows aquifers to carry gound water down dip, so Crowsnest coal basin is also a ground-water basin.

The Crowsnest coal basin has been complicated by faulting. The most intense faulting occurs along the east side of the basin, and is probably related to the Lewis overthrust. Three major structures within the basin include: 1) Michel syncline, at the north end of the basin; 2) Coal Creek basin, east of Fernie and Morrissey Ridges, and 3) McEvoy syncline, in the southeast, and deepest, part of the basin.

Physical Work - 1961

A total of 27 miles of new roads were constructed during 1961 to provide access to drill sites, adit sites, and areas to be trenched and mapped. The cost per mile varied from $300 to $3,300, and averaged about $950. These roads were a major factor in facilitating the trenching and bulk sampling program.

Trenching operations were confined to outcrops along the west side of the coal basin, where 18 ridges were trenched and sampled, and trenches on 13 previously-trenched ridges were cleaned and sampled. A total of 502 channel samples were taken from 25 of the 31 trenched ridges.

By employing the use of air equipment for mining in 1961, a total of 24 adits were driven and 28 bulk samples taken. In addition, 100-lb. channel samples were taken from the face of each completed adit to provide representative samples for microwashing tests.

A total of 4,196 feet was rotary (non-core) drilled in four holes by high-pressure air techniques. Rate of penetration for actual drilling time was 7.0 feet per hour, but average overall drilling rate was only 2.15 due to excessive delays.

A total of 7,426 feet was core drilled in six holes by three companies. Core recovery in coal and bone averaged 60 percent. Overall rate of progress was 0.81 feet per hour.

Drilling performance and cost summaries are tabulated below. Pertinent data on holes drilled are presented in table at end of this Summary.

Summary of Core Drilling, 1961-2

Contractor	Footage Drilled	Percent of Total: Ft. Drilled	Percent of Total: Hrs. Worked	Total Cost Per Ft.	Overall Ft./Hr.
Core Drilling, Inc.	2891	39	36	$24.59	0.88
L. Whatley	573	8	16	43.80	0.38
Canadian Longyear	3962	53	48	39.21	0.91
Totals	7426	100	100	$33.87	0.81

Summary of Drilling Costs - 1961-2

Type of Drilling	Total Footage Drilled	Total Drilling Costs*	Total Cost Per Foot	Overall Feet Per Hour
Non-core (H.P. Air)	4,196	$170,177	$40.56	2.15
Core	7,426	$251,551	$33.87	0.81
Total	11,622	$421,728	$36.29	1.04

*Does not include site preparation or road construction and maintenance costs.

Coal Beds

Thickness and areal extent of the coal beds generally decrease upward from the Basal Kootenay sandstone. Coal beds vary from those that are continuous for several miles to small lenses of local extent. In general, coal is crushed and friable in the lower beds, which have been subjected to the most deformation. Most beds contain high-ash, particularly where coal has been crushed and intimately mixed with partings.

Coal Quality

Petrographic and chemical analyses show that the Cropco coals are medium- and low-volatile bituminous in rank (18 to 31 percent volatile matter). There is a range in volatile matter content of approximately 10 percentage points from the base (lowest V.M.) to the top of the coal measures. There is also a decrease in volatile matter content of upper beds in going down dip from the outcrop. In bed M-9, the change noted is 8 percentage points.

Raw coal is generally high in ash and low in sulfur contents. Ash in adit samples averaged approximately 23 percent on Morrissey Ridge and 24 percent on Fernie Ridge. Most sulfur values range between 0.3 and 0.6 percent.

Carbonization tests show that the samples from the lower beds in Option A are weakly- to non-coking. Evidence indicates that oxidation as it affects coking properties is related to degree of deformation, and does not conform to the level of the water table in the coal beds. The number of beds affected by deep oxidation varies from south to north in the coal basin. On Morrissey Ridge lower beds M-1 through M-4 have been oxidized; on Fernie Ridge oxidation extends as high in the section as bed FE-8, yet none of the beds appear to be oxidized at the north end of Sparwood Ridge (Option B).

Microwashing data from adit channel samples provided the basis for selecting bulk samples for washing, with cutoffs of 70 percent minimum yield and 10 percent maximum ash established as guides. Based on these criteria, 14 of 28 bulk samples were washed at specific gravity 1.55. On Morrissey Ridge only two beds, M-5 and M-9, and on Fernie Ridge only one bed, FE-8, consistently washed to specifications. Two samples from the Balmer Mine (Option B) washed to just under 10 percent ash, with good yields. Refer to Tables XI and XII.

Washed coals producing the strongest cokes were taken from beds M-9 and M-10, and coke strengths were good in blends using up to 30 percent Corbin, Lundale, and Wellington coals. Washed coal yield of bed M-10 is low at outcrop, but quality improves down dip. Coals from beds M-5 and M-6, and from the Balmer Mine, produced fairly strong cokes, but coking pressures were excessive. The only sample from Fernie Ridge that coked was taken from bed FE-B. Bed FE-9, not sampled, was mined for coking coal on the south end of Fernie Ridge (Elk River Colliery). The remaining samples were poorly- or non-coking coals. Coals exerting excessive coking pressures will require blending with non-coking or high-volatile coals.

Estimated Reserves

Estimated reserves presented herein are of a lower magnitude than any of several previous estimates. Reserves were estimated only for coal beds known to contain good coking coals in Option A; namely, beds FE-B, FE-9, M-10, M-9, and M-5. Other beds that coked were either too dirty to wash to specifications or were too limited in areal extent.

It is estimated that property under Option A along Fernie and Morrissey Ridges contains a total of 142 million tons of raw recoverable coking coal, or 113 million tons of washed coking coal, under 2,500 feet of cover (see Table XIII). The grade and reserves, by bed and block, are summarized below.

Estimated Reserves of Coking Coal, Option A

		Washed* Coal, %			Reserves in Millions of Net Tons			
					0-1500 Ft. of Cover		0-2500 Ft. of Cover	
Bed	Block	VM	Ash	Yield	Recoverable	Washed	Recoverable	Washed
FE-B	Fernie Ridge	30.4	5.8	77	13.7	10.6	24.9	19.2
FE-9	Fernie Ridge	32.1*	12.2*	80*	15.4	12.4	29.4	23.5
M-10	Morrissey Ridge	21.4*	16.5*	75*	3.4	2.5	31.7	23.8
M-9	Morrissey Ridge	24.8	6.0	85	8.8	7.5	37.4	31.8
M-9	Morrissey Creek	16.8*	16.2*	75*	2.0	1.5	7.5	5.6
M-5	Morrissey Ridge & Creek	19.7	7.2	85	5.7	4.8	10.8	9.2
Average & Totals				80	49.0	39.3	141.7	113.1

*Asterisk indicates raw coal analyses and assumed washing yield where washing data are not available on controlling samples.

Note: Recoverable raw coal computed on basis of 50 percent of in-place total, or 900 net tons per acre-foot.

Mining Considerations

Approximately 30 percent of estimated coking coal reserves under 1500 and 2500 feet of cover, respectively, occurs in beds which dip between 15 and 30 degrees. This pitch is too steep to maneuver heavy mining equipment and too flat to move coal by gravity. Percentage distributions of reserves by dip and cover intervals are shown below:

Dip Interval, Degrees	Percent of Reserves in Depth of Cover Interval	
	0-1500 Feet	0-2500 Feet
0 to 15	18	49
15 to 30	31	30
30 to 60	51	21
Total	100	100
Total Recoverable Coal, Millions N. T.	49	142

Tight folding which occurs along the outcrop near the basal part of the Kootenay formation may present difficult mining problems in lower coal beds, and may also occur down dip from outcrops. Upper beds have not been affected.

Mining personnel of Crow's Nest Pass Coal Company state that bumps and bursts become serious when cover exceeds 1,500 feet. Approximately two-thirds of estimated potential reserves in Option A have cover ranging between 1500 and 2500 feet.

Roof and floor conditions of most coal beds are considered poor, but there is general improvement from lower to upper coal beds. In places, coal is overlain by firm shale, sandstone, or conglomerate and roof conditions are rated good.

Holes drilled back from the edge of the basin encountered water with natural gas drive, and mining operations extending below surface water drainage will require pumping. Natural gas does not occur in amounts excessive for mining, but ventilation will be an important consideration in mine planning.

There is a large reserve of coal, mostly non-coking, in outcropping beds along Morrissey and Fernie Ridges. Auger and hydraulic mining are currently under investigation to determine if such coals can be economically exploited. Dips are adverse for auger mining, however.

1961-62 CROPCO DRILLING SUMMARY

Hole No.	Interval Footage From	To	Total	Non-Coring (Diameter)	Coring (Core Taken)	Type of Drilling	Inclusive Dates	Rig	Contractor on Hole
BC-1	1934*	2507	573		2"	Wireline	8-3 to 10-13	Mayhew 200	L. Whatley
BC-2	0	2202	2202		2-1/8"	NX Convential	6-5 to 8-31	Sullivan 200	Core Drilling, Inc.
BC-3	0	1762	1762	6-1/4"		High Pressure Air & Rotary	7-28 to 8-25	Ideco M25D	Chupp Well Service, Ltd.
BC-3	1762	2450	688		2"	Wireline & Convential	9-7 to 10-23	Sullivan 200	Core Drilling, Inc.
BC-4	0	1404	1404	6-3/4"		High Pressure Air & Rotary	8-26 to 9-30	Ideco M25D	Chupp Well Service, Ltd.
BC-5	0	945	945	6-3/4"		do.	10-2 to 10-18	do.	do.
BC-5	945	1601	656		1-9/16"	NX Wireline (Oversize O.D.)	3-8-62 to 5-1-62	Longyear 44 Skid Mount	Canadian Longyear, Ltd.
BC-6	0	1776	1776		1-25/32"	NX Wireline Series 10	10-5 to 12-16	Longyear 44 Skid Mount	do.
BC-7	0	80	80	9-7/8		Surface	10-19 to 10-29	Ideco M25D	Chupp Well Service, Ltd.
BC-7	0	1525	1525		1-9/16"	NX Wireline (Oversize O.D.)	11-13-61 to 3-7-62	Longyear 44 Skid Mount	Canadian Longyear, Ltd.
			11,611						
Footage Redrilled			11						
Total Footage Drilled			11,622						

* Hole BC-1 was drilled to depth of 1934 feet by Boyles Brothers Drilling Company, Ltd. in 1960.

PROGRESS REPORT
CROPCO PROJECT, 1961

INTRODUCTION

Purpose and Scope of Investigation

See 1960 Progress Report.

Previous Work

See 1960 Progress Report.

1961 Program

Organization of the 1961 program was directed by Arthur R. Still, of Still & Still, Consulting Mining Engineers & Geologists, Prescott, Arizona. Mr. Still selected or approved all temporary personnel employed for the 1961 field season and directed the project until June 9, 1961. During the remainder of the year, the project was under the supervision of Field Exploration, Columbia Iron Mining Company.

Personnel started to arrive on the project during the latter part of May, but because of snow conditions active field work was delayed until June 1. Field crews were kept at full strength until September, when many of the temporary personnel terminated to return to school. Field work on a limited basis was extended into the late fall; trenching was terminated October 1, geologic mapping October 24, mining of bulk samples November 8, and diamond drilling was suspended December 16. Drilling operations on one rig were resumed early in January 1962, and were terminated May 1, 1962. Results of the 1962 drilling are included in this report.

At full strength, personnel on the project reached a total of 55, as follows: three geologists from Field Exploration, 13 geologists employed on a temporary status, 9 miners for adit work, and 30 men for trenching operations.

Where practical, access roads were constructed for mining and trenching operations, but base camps were established for trenching crews in some of the remote areas. A total of fifteen 4-wheel-drive vehicles (10 purchased and 5 leased) were used to transport field personnel on their respective assignments. A G2 helicopter, under contract from July 11 to September 9, was used to transport mapping parties to and from remote parts of the coal basin.

According to the "Investigation and Option Agreement" Columbia Iron Mining Company may exercise one of two alternatives, described as Option A and Option B. Option A essentially excludes the area surrounding the Michel Colliery, whereas Option B includes all the mining properties and assets of the Crow's Nest Pass Coal Company. The difference of $7,000,000 in the purchase price of these two options was the major factor in concentrating field efforts to date on properties held under Option A.

Geologists were assigned to map specific areas, and each mapping party prepared a written field report covering their area or assignment before leaving the project. These reports are listed, by writer, under references, and they are on file in the Field Exploration office. These field reports were consulted during the preparation of the progress report, and much of the geologic interpretation was taken from them.

M. D. Okerlund, Exploration Geologist, directed the writing and compilation of this progress report.

Location and Climate

See 1960 Progress Report.

Accessibility

Due to re-routing of traffic, made possible by ballast work on existing road beds, the rail distance from Fernie to Vancouver has been reduced from 712 miles to 672 miles. The distance from Vancouver to Pittsburg, California by water, is 854 ocean miles.

PROPERTY DESCRIPTION AND OWNERSHIP

Investigation and Option Agreement

The "Investigation and Option Agreement" held by Columbia Iron Mining Company consists of two parts, Option A and Option B. Under Option A, the operating mines at Michel, all coal beds south of Michel Creek and north of the option boundary, and various coal beds and stripping rights north of Michel Creek are excluded. Option B includes all the "Mining Properties and Assets" of the Crow's Nest Pass Coal Company, Ltd. Purchase prices under these options are $10,000,000 and $17,000,000, respectively, provided that a minimum of $500,000 is expended during the investigation. This minimum figure was exceeded during the 1961 field season. The four-year option terminates on May 1, 1964. The areas covered by each option are shown on geologic map 6L-160.

Property Description

For detailed descriptions of properties, refer to the 1960 Progress Report. Outlines of properties are shown on Map 6C-403, this report.

THE CROW'S NEST PASS COAL COMPANY, LIMITED, PROPERTY MAP
250,000 Acres - Approximately

HISTORICAL SKETCH

Freehold Lands

1889 - British Columbia Government Crown granted to E. Bray, et al, Lots 81 to 86 (6 lots) on Martin Creek, containing 2,409 acres.

1889 - E. Bray, et al, deeded above lots to Crow's Nest Coal & Mineral Company, Ltd.

1890 - British Columbia Government Crown granted to the Crow's Nest Coal & Mineral Company Lots 151 to 171 (20 lots), containing 7,800 acres.

1893 - Crow's Nest Coal & Mineral Company deeded the above 26 lots (10,209 acres) to the British Columbia Coal, Petroleum & Mineral Company.

1897 - British Columbia Coal, Petroleum & Mineral Company deeded these lands to the Kootenay Coal Company.

1897 - Corporate name of Kootenay Coal Company was changed to The Crow's Nest Pass Coal Company, Limited.

Subsidy Lands

1888 - E. Bray, et al, were incorporated as the Crows Nest & Kootenay Lake Railway and, by another act, this company was granted land for a right-of-way.

1890 - Railway Act of 1890 granted that company 20,000 acres per mile of rail completed, lands to be in alternate blocks, with a 20-mile frontage on the right-of-way.

1891 - Name changed to British Columbia Southern Railway.

1897 - Federal Government granted a charter to C.P.R. for construction of a railroad through Crowsnest Pass, with a subsidy of $11,000.00 per mile, with the condition that, if the C.P.R. obtained land either through agreement with another company or with the British Columbia Government, 50,000 acres would be retained by the Crown.

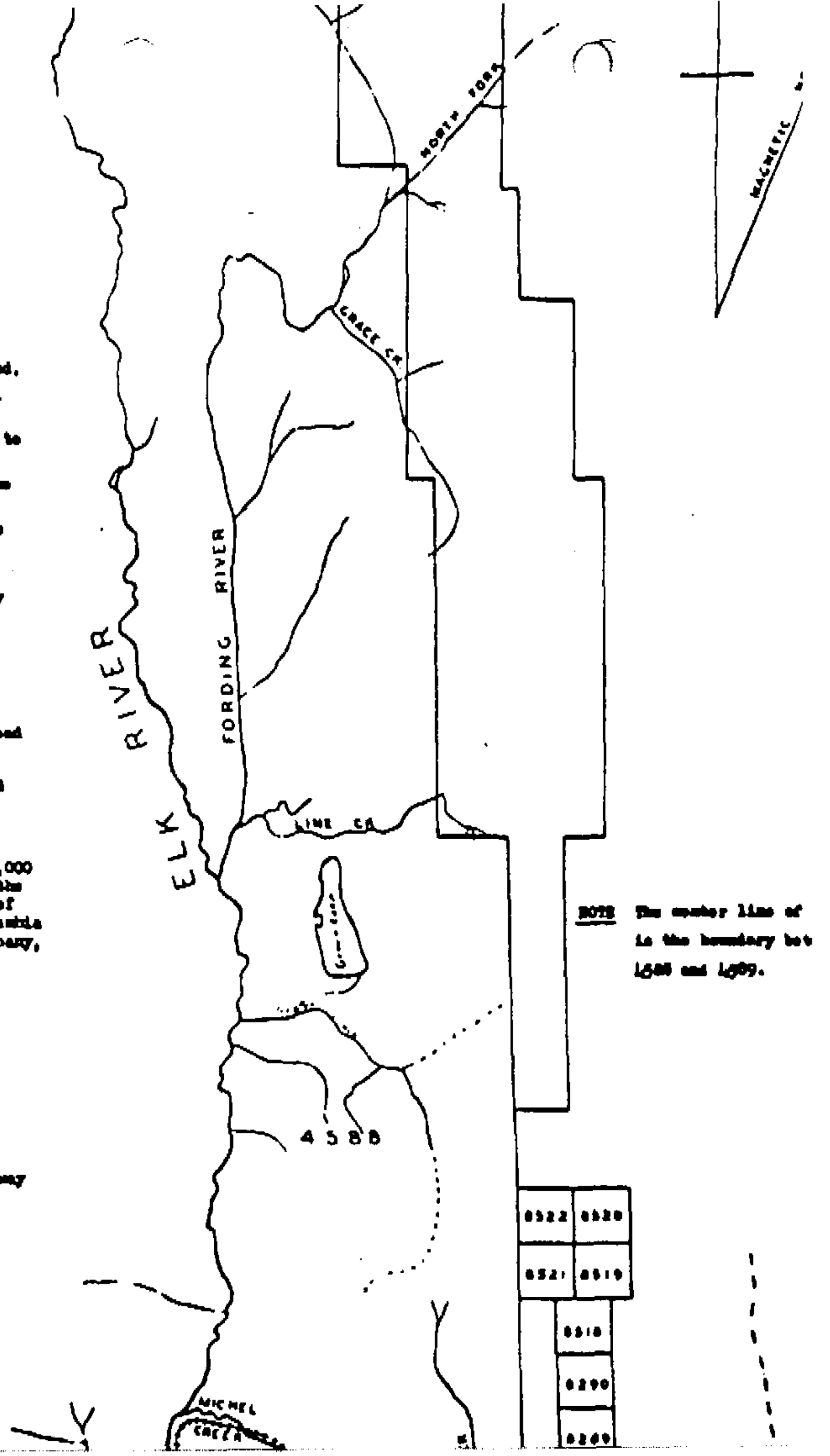
1897 - Agreement between C.P.R., British Columbia Southern Railway, and Kootenay Coal Company resulted in the following: British Columbia Southern Railway agreed to convey 50,000 acres to the Crown, 3,840 acres to C.P.R., and 250,000 acres, approximately, to The Crow's Nest Pass Coal Company, Limited, with the exception of the 3,840 acres of C.P.R. reserve at Bossmer, and 5,000 acres of Crown land contained therein. To make up the deficiency, the British Columbia Southern Railway granted the 10,000 acres to The Crow's Nest Pass Coal Company, Limited, in the Lodgepole area.

The Crow's Nest Pass Coal Company, Limited, land holdings, therefore, as a result of the above agreements, statutes and freehold grants, were:

1.	Freehold Grants	10,209.0	Acres
2.	Fernie Townsite Block	614.7	"
3.	Morrissey	371.5	"
4.	Deficiency Block	10,000.0	"
5.	"Railway Act" Grant	227,838.95	"
	Total:	249,034.15	Acres - Date, 1897.

1904 - Crow's Nest Southern Railway (C.P.R.) deeded to the N. P. & M. Railway 1.41 acres at Swinton - total, then, 249,035.56.

April 20, 1956



HISTORY, DEVELOPMENT AND PRODUCTION

The only change since the 1960 Progress Report was written, is production for the past year, so the reader is again referred to that report. Coal produced by Crow's Nest Pass Coal Company, Ltd., in 1961 totaled 792,050 net tons. Of this, 713,059 tons came from underground mining and 78,991 tons from strip operations.

GEOLOGY

General Discussion

The Crowsnest coal basin is a structural basin wherein the coal-bearing Kootenay formation and other rocks of Mesozoic age have been preserved from erosion. Older rocks of Paleozoic and Precambrian ages, which have been extensively folded and faulted, completely surround the basin (see Map 6M-321). The Kootenay formation is not so extensively deformed because the Fernie shale, which lies between the Kootenay formation and the Paleozoic sediments, has absorbed some of the stresses that caused the deformation of the older rocks. There are places, in particular the east side of the basin, where the underlying structures cut across the Fernie shale and into the Kootenay formation, and the Kootenay formation is in fault contact with Paleozoic sediments.

The investigation, to date, has been limited to the Crowsnest coal basin because of access and the relative abundance of coal beds in the basin. There is, however, an occurrence of the Kootenay formation north of the Crowsnest coal field, a part of which is included under the "Investigation and Option Agreement." This area lies east of Elk River about 20 miles north of Michel.

There is no uniformity or agreement on the limits and formation names of the sedimentary rocks overlying the Kootenay formation. McEvoy (1900) applied the term "Elk Conglomerates" to a sequence of conglomerates, sandstones, and shales which overlies the coal measures. In 1933, MacKay proposed that McEvoy's "Elk Conglomerates" be included as part of the Blairmore formation, but Newmarch (1953) disagrees with this nomenclature on the basis of Kootenay flora occurring in the "Elk Conglomerates" and suggests the term "Elk formation" for a "thickness of approximately 1,700 feet of dark shales, sandstones, and hard cliff-forming conglomerates, which overlies the Kootenay coal measures in the Fernie area". Newmarch states that the upper part of the Kootenay formation grades into the Elk formation, but he arbitrarily places the contact at the base of a coarse conglomerate which overlies the "B" coal seam, "so that all the known commercial coal seams are contained within the (Kootenay) formation".

Rather than relying on any one of the proposals stated above, it was decided for ease of mapping to make the formation breaks on the basis of lithology. On the west side of the basin, where the rocks are well exposed, a sequence of shales, sandstones (in places conglomeratic), and coal beds underlies a sequence of sandstones, chert-pebble conglomerates, and shales. The upper rocks crop out as massive ledges in marked relief with the more subdued topography of the underlying rocks. This rather abrupt change, from a ratio of predominately fine-grained clastic sediments, containing abundant carbonaceous material to coarse-grained clastic sediments, containing relatively little carbonaceous material, was found throughout the basin, and was mapped as the contact between the Kootenay and Elk formations.

Because of the limited time available, the large area being mapped, and the relative unimportance to the economic study of the coal deposits, the Elk and overlying Blairmore formations were mapped as one unit. The basal conglomerate of the Elk formation and the basal sandstone of the Kootenay formation, a blanket-type sandstone found throughout the coal basin and locally referred to as the Baskoo sandstone, served as excellent marker horizons and were mapped as individual units.

To standardize and correlate data between the different areas, a set of "Suggested Field Procedures for Mapping Coal Deposits" (included in Appendix) was given to each geologist and a one-week indoctrination course was conducted for all geologists at the beginning of the field season to familiarize them with the geology and physical features of the basin.

Mapping was done on aerial photograph contact prints (1:24,000) and the geology was transferred in the field office to topographic base maps of the same scale with a Kail Plotter. Sections were measured along the crests of

Figure 1

Aerial view of Morrissey Ridge, looking northerly. Sandstone and conglomerate beds of the Elk formation (Ke) form the steep slopes of the upper part of the ridge. The Kootenay (coal-bearing) formation (Kk) underlies the Elk and occupies the central portion of the ridge. The Fernie (shale) formation (Jf) forms the brush-covered slopes under the Kootenay.

31 small transverse ridges on the west side of the basin, and trenches were dug into the coal beds. Geologists measured and described the rocks, with emphasis being placed on coal, of the entire Kootenay formation and into that part of the overlying Elk formation that contains coal beds of significant thickness.

Stratigraphy

Sedimentary rocks in the area range in age from Paleozoic to Quaternary and are mapped in six units as follows: 1) Paleozoic rocks (undifferentiated), 2) Fernie Group and Spray River formation (undifferentiated), 3) basal Kootenay sandstone, 4) the coal-bearing Kootenay formation, 5) basal Elk conglomerate, and 6) the Elk and Blairmore formations, which also contain some coal. A generalized section of strata for Crowsnest Coal basin is shown in Table I.

TABLE I

GENERALIZED SECTION OF STRATA
CROWSNEST COAL BASIN

Age	System	Formation	Thickness (Feet)	Description and Remarks
Mesozoic	Cretaceous	Blairmore	7,000	Conglomerate, sandstone, and vari-colored shale; from a distance has the appearance of "red beds".
		(Disconformity)		
		Elk	1,700	Chert-pebble conglomerate, sandstone, shale, and some coal beds; conglomerate and sandstone beds form ledges.
		Kootenay	1,800-2,200	Sandstone, shale, carbonaceous shale, and coal beds; most sandstones are lenticular, but basal sandstone (Baskoo) occurs throughout coal basin.
	Jurassic	Fernie	3,000	Grey to black calcareous shale with some sandy beds; spherical concretions occur near top.
		(Disconformity)		

Table (con't)

Age	System	Formation	Thickness (Feet)	Description and Remarks
	Triassic	Spray River	1,700	Shaley quartzite, sandy shale, and argillaceous dolomite.
		(Disconformity)		
Paleozoic	Undifferentiated		?	Calcareous and arenaceous sediments; surround Crowsnest coal basin.

Paleozoic

Rocks of Paleozoic age completely surround the Crowsnest coal basin, but they have relatively no significance in the evaluation of the coal deposits within the basin. No attempt was made, therefore, to describe the Paleozoic rocks, and they are mapped only in those areas where they are close to the Kootenay formation. They consist essentially of calcareous and arenaceous sediments that generally stand out in bold relief, as compared to the softer formations of lower Mesozoic age.

Triassic-Jurassic

Spray River and Fernie Formations - Newmarch (1953) describes the Spray River formation as "an assemblage of shaly quartzites, thin-bedded sandy shales, and argillaceous dolomites". According to Telfer (1933), the formation is 1,700 feet thick near Fernie, where it is composed of shale and dolomitic limestone. It is reported to have an erosional unconformity at the base and a regional disconformity with the overlying Fernie formation.

The Fernie formation consists of grey to black calcareous shales with some resistant sandy beds. Spherical concretions, averaging about one inch in diameter, occur in the upper 200 feet of the formation. The shale typically weathers to a uniformly light brown soil. Although the formation is contorted and the base is not exposed in the Fernie area, it is estimated to be in the order of 3,000 feet thick (Newmarch). An eastward thinning of the formation occurs, with the thickness of the east side of the basin being only 900 feet.

PHYSICAL WORK, 1961

Road Construction

Roads to holes BC-1 and BC-2 were constructed during 1960, but in order to move drilling rigs on these sites early in the 1961 season, snow had to be removed and the roads repaired during the latter part of May. Two roads were constructed on Fernie Ridge, and several old logging roads were repaired on Hosmer Ridge to provide early access to the Kootenay formation for trenching and geological crews. Most of the other road construction was delayed until later in the season, when the ground had dried out.

All adits driven in 1961 were made accessible by roads. The Basal Kootenay sandstone was crossed on Fernie ridge FE-10, and an access road was extended to the top of the Kootenay formation. On Morrissey Ridge, access roads were extended southward from ridge M-18 to ridge M-20, and northward from ridge M-9 to ridge M-4. Roads were built to adit 13 on the north side of Coal Creek, and to adits 17 and 18 on the south side of Coal Creek. A road was also built to the base of the Kootenay formation on Sparwood Ridge for the purpose of sampling the basal coal bed in 1962.

Roads constructed to proposed drill sites include the site north of Coal Creek and west of hole BC-3, the road along Marten Creek, and two drill sites on Mt. Baldy.

A total of about $26,000 was expended for the construction of about 27 miles of new roads for an average cost per mile of $950. The cost per mile ranged from $300 for roads constructed in the Fernie formation to $3,300 for the access road to hole BC-6, where considerable rock work was required. In addition to the cost of new roads, about $20,000 was expended for plowing snow, repairing roads, preparing drill sites, and moving and servicing drilling equipment.

Trenching

Trenching operations, as described in the 1960 Progress Report, were continued during 1961. A total of 30 men were employed for this work, but some of the men were transferred to work with geologists, and a two-man party was assigned to sample coal beds in the trenches. One foreman was in charge of all trenching operations, and crews were made up of four to six men with a "lead trencher" in charge of each crew.

Trenching was confined to outcrops along the west side of the coal basin, where 17 ridges were trenched and the trenches on 13 ridges, previously trenched in 1960, were cleaned for sampling. One ridge, FL-7, was trenched by the pipeline crew during the laying of the Alberta Natural Gas pipeline. After the trenches were dug and cleaned, geologists measured and described the rocks on each ridge, including the trenches. The trenches exposed the coal beds for detailed measurements to the nearest 0.1 foot. Geologists marked sample breaks in the trenches for coal beds having a thickness of 5.0 feet or more, and channel samples were taken by one sampling crew which was trained by a geologist. The maximum for any one sample was limited to a 10-foot bench thickness. Rock partings up to 0.5 feet thick were included in the channel sample, and partings over 0.5 feet were excluded. A total of 502 channel samples were taken from 25 of the 31 trenched ridges.

The measured section for each ridge was plotted on a scale of 1 inch to 100 feet, and the detail of the coal beds on a scale of 1 inch to 10 ft. (see Maps 6M-422 through 452). These sections served as control points for the correlation diagrams, Maps 6L-161, 162, and 166.

<u>Mining and Bulk Sampling</u>

Mining and bulk sampling was accelerated over 1960. A total of 21 four-ton and 7 two-ton samples were taken from 24 adits. A 9-man crew was used both years, but in 1961 air compressors, air drills, and air picks were made available to the miners. During 1960, all mining was done by hand tools, but roads were built to all adit sites driven in 1961 so that machinery could be used in the adits. This increased the rate of driving the adits from 0.8 to 2.0 feet per man shift. The cost per foot dropped from $22.44 to $17.71, and the cost of air drilling equipment was completely written off during 1961.

The practice of taking a channel sample every 10 feet of advance to check the volatile matter content and coking index was continued. This information served as a guide to determine when fresh (unweathered) coal was encountered, and this was generally found about 50 feet in from the outcrop.

In addition to the bulk samples, channel samples (100-pound) were taken from the face at the end of each adit. In the thicker beds, these samples were taken on benches, based on the lithology of the coal bed, with a composite for the entire bed (see adit drawings). The purpose of these samples was to provide a representative sample for microwashing tests. Selection of bulk samples to be washed was based on the microwashing results.

With the exception of adit 13, which is in the "B" bed on the north side of Coal Creek, the locations of the adits are shown on the correlation diagrams (see Maps 6L-161 and 162).

The goal of the 1961 sampling program was to obtain a bulk sample from each coal bed of minable thickness at two locations on Morrissey Ridge (samples were obtained from the beds of minable thickness of ridges M-9 and M-10 during 1960), and at one location on Fernie Ridge. This goal was not completely realized before mining operations were curtailed because of inclement weather, but roads were constructed to all locations selected for sampling.

Mining and bulk sampling data for 1961 are tabulated in Table II.

<u>Project Costs</u>

The Type B expenditures for the Cropco Project are shown by year and expense classification in Table III. The costs for 1960 and 1961 are official costs obtained from the Accounting Department in San Francisco, whereas the costs for 1962 are taken from current project records, and are subject to correction and refinement.

Table III
Project Costs

Code No.	Expense Classification	1960	1961	1962*	Total
51	General Administration	$ 30,716	$ 21,159	$ 0	$ 51,875
52	Property Acquisition	0	0	0	0
53	Equipment	18,035	23,830	0	41,865
54	Inventory	2,118	30	0	2,148
55	Surveying and Geology	35,859	75,055	7,125	118,039
56	Construction	7,257	45,226	3,782	56,265
57	Drilling	61,532	347,705	86,479	495,716
58	Underground Workings	19,963	29,708	1,007	50,678
59	Special Services	9,850	33,413	297	43,560
60	Miscellaneous	6,799	16,163	950	23,912
	Totals	$192,129	$592,289	$99,640	$884,058

*Estimated costs - subject to revision.

Above costs do not include $68,000 for 1961-62 analytical work.

Non-Core Air Drilling

In 1960, Boyles Bros. Drilling (Alberta) Ltd. was awarded the drilling contract at Cropco, and drilled a total of 1934 feet in hole BC-1 over a period of three months. Much of the difficulty experienced in this hole was attributed to the extreme hardness of conglomerates encountered in the Elk Formation and to the occurrence of artesian water. In planning the drilling program for 1961, it was decided to use air-rotary-percussion (non-core) drilling to penetrate the hard conglomerates overlying the coal measures. This action was deemed advisable in order to make up for the small amount of drilling in 1960, and to obtain drill hole data critically needed to evaluate down-dip areas behind the outcrops. Completion of the holes was then to be accomplished with rigs employing diamond coring procedures.

On July 30, 1961, equipment for air rotary drilling had been mobilized from Canada and the United States to Fernie, B. C., preparatory to drilling. The plan called for using a slim-hole (oil field type) rig and high pressure air to activate a Mission down-the-hole rotary-percussion hammer adapted for tri-cone bits. It was believed that the use of this type of equipment, although expensive, would be justified because of high penetration rates. Contractor for the air drilling was Core Drilling Incorporated, Denver, Colorado.

The operating procedure was to start a hole with a large size bit, 12-1/2 to 12-3/4 inches, drill to approximately 30 feet, and case with 25 feet of 10-3/4 inch casing. A 6-3/4" diameter hammer and 9-7/8" to 9" hard-formation tri-cone bits would then be used to a depth of at least 400 feet, driven by two Joy 750 cfm compressors and one Joy 2000 cfm booster. This hole was cased with 7" to 7-5/8" diameter casing. Water intersected in each of the holes at 400-foot depths varied from 20 to 60 gpm, but was successfully sealed after casing.

A 5-1/4" diameter hammer and 6-3/4 to 6-1/4" hard-formation tri-cone bits were then used, and the hole would be drilled as deep as possible, employing the two compressors and one booster. Holes BC-3, BC-4 and BC-5 were air-drilled to 1767, 1404 and 945 feet depths, respectively. Hole BC-7 was stopped at a depth of 80 feet, after numerous difficulties. The three deep holes were stopped because of coal caving and sticking the tools in the hole. The holes were then cleaned out with heavy mud and 4-1/2" casing would be set to accommodate subsequent core drilling operations.

The coal beds that were drilled were sampled by diverting the air-water cuttings from the blow pipe into a large diameter pipe 35 feet long. This large pipe would succeed in slowing the velocity of the airstream and permit coal cuttings to drop out and collect in the pipe. Sufficient data were not gathered to compare the accuracy of results of air samples versus core samples.

Drilling Equipment and Contractor Prices

Drilling equipment mobilized for air drilling consisted of: one Ideco M-25-D drill rig with a 65-foot mast; 60-bbl. mud tank, 6-1/2" x 12" mud pump; 3080 ft. of 2-7/8" IF range 1 drill pipe; 90 ft. of 4-3/4" x 2-1/2" drill collars, and accompanying hand tools. This drilling equipment, including the operating crews and tool pusher, was leased by Core Drilling, Incorporated, from Chupp Well Service, Ltd., Red Deer, Alberta. Charges for the equipment and personnel amounted to $30 per hour for operating and $25 per hour for moving and standby time. The costs of bits, mud, lost circulation materials, fuel, casing and other materials used, including fishing tool rentals, were invoiced to CIM at contractor's cost.

Compressed air equipment used consisted of: two Joy Tornado 750 cfm-265 psi compressors; one Joy two-stage Tornado, 1500 psi booster; an injection pump and tank; Mission air hammers, 5-1/4" (300-600 cfm) and 6-3/4" (325-1300 cfm); and service crew of two. Prices for the above air equipment and services were as follows:

Compressors and booster - $50/day and $6.50/hr. while operating, for each unit
Two-man Crew - $120/day while operating and $90/day for standby
Injection pump & tank - $25/day while operating and $10/day standby
Mission Hammerdrill - $75/day fixed charges plus $10/hr. while operating
Drill pipe float - $25/day for first day and $3/day for subsequent days

Charges for fuel, grease, moving from hole to hole, injection of soap, and other items were separate from above charges and were billed at contractor's cost.

Performance

From July 30 to October 29, 1961, four holes were drilled by air, aggregating 4196 feet of hole. Penetration rates through the conglomerates, sandstones and shales were quite satisfactory considering the large volume of water being made in the holes as they were drilled (see Maps 6C-544A, 545, and 546A). The number of feet drilled per hour of drilling for the four holes averaged over seven feet. Drilling through the coal beds with the air hammer tool progressed rapidly, but the coal beds generally caved within a few feet of advance below the bed, requiring changes in drilling techniques. The hole would then have to be cleaned out with mud, reamed, and casing set.

A breakdown of the hours for each of the holes is shown in Table IV. The average overall drilling rate was 2.1 feet per hour for the four holes, which is quite slow for the size and amount of equipment mobilized for the job. This was due basically to four reasons: (1) inexperience of the crew in air drilling techniques; (2) the drilling rig used was not ideally adapted for air drilling; (3) the coal beds are severely eroded by this method of drilling and present caving problems; and (4) large volumes of water encountered.

Inexperience in air drilling accounted for excessive amounts of fishing and reaming time (18.8 percent of total time). Bits were left on too long, or too much weight and/or air pressure was used on the hammer, knocking off the cones from the bits or resulting in excessive loss of gauge. Fishing was necessitated for lost cones and bearings, and reaming was required where the gauge of the hole was lost. The type of rig used was not readily adaptable to air drilling, for it had just come off work-over and service jobs in the oil fields and had not been used for drilling. The rotary table proved to be too small to allow a rotating head (part of a blow-out preventor) to pass through so that the kelly and larger bits had to be broken below the table without benefit of using breakout tongs. These factors contributed to excessive amounts of time in setting up, tearing down and in trip time.

Table IV
Performance
Non-Core Air Drilling

Hole	Footage Drilled	Shifts Worked	Hours Worked: Total	Set-up	Drilling	Trip Time	Reaming	Casing	Hammer Delays	Cementing, Other Hole Delays	Mechanical Repairs	Fishing	Sampling	Feet/Hour Overall
BC-3	1767	84	672	97	203	89	19	80	28	29	62	41	24	2.6
BC-4	1404	108	696	27	218	126	80	32	10	83	0	116	4	2.0
BC-5	945	54	432	64	111	38	63	52	5	66	5	25	3	2.2
BC-7	80	19	152	56	22	6	16	15	4	15	10	8	0	.5
Totals	4196	265	1952	244	554	259	178	179	47	193	77	190	31	2.1
% of Hrs. Worked			100.0	12.5	28.4	13.3	9.1	9.2	2.4	9.9	3.9	9.7	1.6	xxx

Costs

Total cost of air rotary drilling was $170,176.90, in drilling four holes and a total footage of 4196 feet. The overall average cost per foot was $40.56. A breakdown of the cost for each hole is shown in Table V.

For reasons given in the preceeding section on performance, air rotary drilling did not prove to be an economic way of drilling at Cropco. The penetration rate per hour of actual drilling with air in 1961 was $3\frac{1}{2}$ times greater (7.0 vs 2.1 ft./hour) than that attained in 1960, but large operating delays with attendant high standby costs on equipment resulted in unfavorable unit costs. The overall drilling rate for non-core drilling in 1961 was 2.1 feet per hour, compared to 1.3 feet in 1960 for the one hole drilled (both non-coring and coring).

Table V
Costs of Non-core Air Drilling
(Total Costs and Cost per Foot)

Hole No.	Footage Drilled	Air Equipment and Servicing	Drill Rig and Crew	Bits	Fuel	Casing	Mud Cement Circulation	Moving	Fishing and Other	Total	Cost Per Foot
BC-3	1767	$17,260.30	$18,326.25	$10,104.43	$2,803.68	$4,406.14	$ 255.00	$2,000.00	$1,696.00	$ 56,851.80	$ 32.17
BC-4	1404	21,447.85	24,760.00	10,603.00	3,600.00	4,672.48	1,558.50	1,125.00	3,084.65	70,851.48	50.46
BC-5	945	10,516.18	12,423.75	3,200.00	400.00	592.50	720.00	1,300.00	175.00	29,327.43	31.03
BC-7	80	2,591.19	4,225.00	564.00	400.00	120.00	105.00	645.00	4,496.00	13,146.19	164.33
Total	4196	$51,815.52	$59,735.00	$24,471.43	$7,203.68	$9,791.12	$2,638.50	$5,070.00	$9,451.65	$170,176.90	$ 40.56
Cost Per Foot		12.35	14.24	5.83	1.72	2.33	0.63	1.21	2.25	40.56	xxxxx

Core Drilling

Distribution of diamond drilling specifications and invitations to bid were extended to nine drilling contractors in April 1961. Bids were received from only two companies, Core Drilling Inc., and Boyles Bros. Drilling (Alberta) Ltd., for the coring work. Proposals were made later by three companies for non-core drilling equipment.

Core Drilling Inc. Denver, Colorado, the successful bidder, moved a Sullivan 200 truck-mounted rotary rig onto location June 2, 1961, and started drilling hole BC-2 three days later. Operations by Core Drilling Inc., continued 24 hours per day, 7 days per week until released on October 29, 1961. During this period, a total of 2891.4 feet of hole was cored by the Sullivan rig (2201.5 feet from surface in hole BC-2; 687.9 feet from 1762.5 feet to 2450.4 feet in hole BC-3; and 2.0 feet in hole BC-5). The reason for release was lack of satisfactory progress.

After many delays, Core Drilling Inc., provided the second of two rigs for coring work on August 3, 1961. A Mayhew 2000 rotary rig owned by Leon Whatley, Grand Junction, Colorado, was moved onto hole BC-1, under sub-contract to Core Drilling Inc. Until released on October 13, 1961, Whatley cored hole BC-1 from 1934.5 to 2507 feet, a total of 572.5 feet. Reason for release was lack of satisfactory progress.

In order to meet proposed 1961 drilling objectives, a contract was made with Canadian Longyear, Ltd., of North Bay, Ontario, to provide conventional diamond drills employing wire-line coring techniques. Longyear commenced setting-up a skid-mounted Longyear 44 drilling rig which had been released from the Smoky coal project, Alberta, at site BC-6 on October 5, 1961, and drilling was begun on October 13. A second (New) Longyear 44 rig was mobilized and moved onto location at hole BC-7 on November 13. Rigs and site installations were winterized for severe cold-weather operations.

By December 16, 1961, when operations were temporarily halted for a holiday recess, hole BC-6 had been cored to 1775.8 feet and hole BC-7 to 1149.9 feet. Because of a prior commitment, the rig on hole BC-6 was released at this time to go on a job in Northern Saskatchewan.

Winter drilling resumed January 8 on BC-7, and operations continued with only the one Longyear 44 rig until April 23, 1962. Hole BC-7 was abandoned at 1149.9 feet after a cement job flash-set with rods in the hole. A second attempt was made and the hole was bottomed at 1525.2 feet following a second loss of rods due to another erratic cement job. The rig was moved to BC-5, and this hole was cored from 940 to 1601.1 feet. Hole BC-5 was wedged and redrilled from 1124 to 1409.3 feet, in an attempt to improve core recovery in coal beds.

All rigs were equipped with Eastman Star Recorders. Information recorded was used to plot penetration rate graphs, which were in turn used for correlation purposes and to evaluate drilling performances.

Directional surveys and gamma ray-neutron logs were run following completion of holes where possible. Gamma ray-neutron surveys were found valuable in delineation of coal from other sediments. Coal beds can be accurately detected and relative ash content inferred, thus reducing the necessity for redrilling in intervals of low or zero coal recovery.

Core Recovery

A total of 1,016.7 feet of coal and bone were cored, and 612.0 feet, or 60 percent, were recovered in 1961 and 1962 drilling programs. Sampling techniques and coring equipment which obtained satisfactory results in other coal fields were utilized in attempting to improve core recovery. The low core recovery is attributed to crushed and poorly consolidated nature of the coal and complicated by emission of natural gas and water under pressure. Drive sampling was also attempted, but shale partings in the coal beds prevented the effective use of drive sampling equipment.

The primary reasons for low recovery of coal at Cropco are:

1. Soft, intensely shattered nature of coal.
2. Release of water and natural gas under pressure from coal beds.
3. Numerous shale and bone partings within coal beds.

Due to its soft and shattered nature, the coal is poorly consolidated and does not form competent core. The release of water and gas under pressure assists in disintegration of the core. Drilling mud was helpful in giving body to this soft material, but did not overcome all of the problems involved. Conventional friction type core lifter springs were not able to hold soft coal in core barrel inner tube, and suction created as barrels were pulled from hole sucked coal core from barrel. Dry blocking was tried to correct this difficulty with some success, but this procedure decreased chances for good recovery on a following run. Hard cake created by dry blocking had a tendency to abrade soft coal to be cored beneath the cake. Coring heads became clogged and tools had to be pulled with every run to clean bit. Conventional tools had been abandoned before completion of the first hole, and excessive trip time at depth defeated the advantage of wire line drilling.

Many thin shale and bone partings were included in coal beds. These partings would break loose and ride on top of coal being cut, grinding it away. Soft, sloughing coal also permitted previously cored partings to cave into the hole and grind core.

To decrease grinding of core by caving material, runs were temporarily limited to a three-foot maximum. Results showed no improvement, since arbitrary limitations of runs caused similar core losses. If a run was bottomed in soft coal, core was lost from the core lifter spring and washed away in subsequent runs. Percent core recovery varied little for coal cored in holes BC-1, BC-2 and BC-3, as shown in the following table:

DDH	0-3' Runs Coal Cut	Coal Rec.	%	3-5' Runs Coal Cut	Coal Rec.	%	Over 5' Runs Coal Cut	Coal Rec.	%	Totals Coal Cut	Coal Rec.	%
BC-1	8.5	2.9	34	5.6	1.7	30	106.2	63.8	60	120.3	68.4	57
BC-2	46.8	34.0	73	91.4	59.0	65	211.3	128.2	61	349.5	221.2	63
BC-3	10.4	4.9	47	50.9	28.6	56	49.3	26.9	55	110.6	60.4	55

Following the above core recovery study, restrictions on length of run were lifted and runs were bottomed by field observation. It seemed logical in light of previous coal coring experience to bottom runs in hard partings so each run would have a solid top and bottom. This practice proved difficult to follow at Cropco since the soft nature of the coal made it impossible to determine if coal was being cored or ground. Longer runs risked grinding more core.

Drive sampling methods were attempted in redrilling of No. 10 seam in hole BC-5 in an effort to improve recovery. A 3 inch O. D., 5-foot solid barrel sampler, equipped with a tungsten carbide tapered drive shoe, unrestricted trap, and fluid ball check valve was used. Repeated attempts at securing a sample were made. Bone and shale partings in the coal bed prevented driving the tube, and sampling was completed by coring methods.

Coal core recoveries for total Cropco drilling are tabulated below:

DDH	Contractor On Hole	Hole Size (Inches)	Core Size (Inches)	Total Coal Cut Ft.	Total Coal Recovered Feet	Percent Core Recovery
BC-1	Boyles Bros.Ltd. 1960	3 7/8	2 7/8	35.1	8.6	25
BC-1	Leon Whatley	3 3/4 & 3 7/8	2" minus	85.2	59.8	70
BC-2	Core Drilling	3 7/8 & 4 7/8	2 1/8	349.5	221.2	63
BC-3	Core Drilling	3 7/8	2 1/8 & 1 7/8+	110.6	60.4	55
BC-5	Can. Longyear,Ltd.	3 1/8	1 9/16	113.0	52.5	46
BC-5 Redrill	" "	"	"	44.7	23.1	52
BC-6	" "	3	1 22/32	188.3	113.0	60
BC-7 1st	" "	3 1/8	1 9/16	79.1	47.1	60
BC-7 2nd	" "	"	"	46.3	34.9	75
Total				1051.8	620.6	59

Data were furnished to Field Exploration by Crow's Nest Pass Coal Company, Ltd. on diamond drilling performed by them on this property. They cored a total of 3644 feet in 19 diamond drill holes. A total of 774 feet of coal was cut and 61 feet recovered, for an overall recovery of 7.9 percent.

In summary, relatively low core recovery was experienced because coal was either ground during coring, or cored and lost from the barrel as the tube was retrieved from the hole. No positive method of insuring coal core recovery was found. As far as can be determined, however, the 59 percent average recovery obtained gave analytical results consistent with those from correlatable beds at outcrop locations.

Performance

Comparison of drilling contractors by their performance is shown in Table VI. Variations in each contractor's performance were primarily caused by circumstances unique to the hole being drilled.

Costs

Ground conditions presented complex and costly drilling problems, primarily due to intensely broken ground and gas-driven water contained in coal beds, sandstones, and secondary structures. Three core drilling contractors drilled a total of 7,426 feet in six holes, in 1961-2. The total cost of this drilling was $251,551.44, or $33.87 per foot, as shown in Table VII.

TABLE VI

PERFORMANCE
Diamond Core Drilling

Hole Number & Contractor	Footage Drilled	Shifts Worked	Hours Worked & Per Cent of Total: Total	Drilling	Ream & Case	Set Up & Tear Down	Mix Mud & Fill Hole	Cementing & Drilling Out	Repairs	Other (Fishing, Stuck in Hole, Stand By)	Feet Drilled Per Hour Drilling	Feet Drilled Per Hour Overall
BC-1 Leon Whatley	572.5	177	1510	535½ 35%	72 3/4 5%	35½ 2%	55½ 4%		132 9%	678 3/4 45%	1.07	0.38
BC-2 Core Drilling Inc.	2201.5	232	1980	1243½ 63%	41½ 2%	29 1%	189½ 10%	12 3/4 1%	253 3/4 13%	210 10%	1.77	1.11
BC-3 Core Drilling Inc.	687.9	154	1232	706 57%	61 5%	130½ 11%	19½ 1%		81½ 7%	233½ 19%	0.97	0.56
BC-5 Core Drilling Inc.	2.0	11	80½		78½ 98%					2 2%		
BC-[illegible] Can. Longyear Ltd.	661.1	129	1141	460½ 40%	31½ 3%	139 12%	72½ 6%	217½ 19%	30½ 3%	189½ 17%	1.44	0.58
BC-6 Can. Longyear Ltd.	1775.8	124	1360	419 31%	56 4%	94 7%	235 17%	94 7%	74 5%	388 29%	4.24	1.31
BC-7 Can. Longyear Ltd.	1525.[illegible]	212	1869	692½ 37%	340 18%	132 7%	21 1%	137 7%	50 3%	496½ 27%	2.20	0.82
Totals	7426	1039	9172½ 100%	4057 44%	681¼ 7%	560 6%	593 6%	461¼ 5%	621 3/4 7%	2198¼ 25%	1.83	0.81

Contractor	Footage: Drilled	Footage: Percent of Total	Hours Worked: Total	Hours Worked: Percent of Total	Feet Drilled Per Hour - Overall
L. Whatley	572.5	8	1510	16	0.38
Core Drilling	2891.4	39	3292½	36	0.88
Longyear	3962.1	53	4370	48	0.91
Total	7426.0	100.0	9172½	100.0	0.81

TABLE VII

1961-62 CORE DRILLING COSTS*

Hole No.	Footage Drilled	Labor & Machine Costs	Labor & Machine Cost/Ft.	Diamond Costs	Diamond Cost Per Ft.	Spec.Equip. Supplies & Subsistence	Spec.Equip. Supp.Subs. Cost/Ft.	Mobil. Mud Cement	Mobil.,Mud Cement Cost Per Ft.	Total Cost	Per Ft.	Contract Type	Contractor
BC-1	572.5									25,075.94	43.80	Combined Footage & Footage + Hourly	Leon Whatley
BC-2	2201.5									39,448.76	17.92	Footage	Core Drilling Inc.
BC-3	687.9									28,324.65	41.18	Footage + Hourly	Do.
BC-5	2.0									3,331.20	1,665.60	Cleaning Hole Hourly	Do.
BC-5	661.1	11,862.50	17.94	5,078.44	7.68	14,803.00	22.39	3,293.79	4.98	35,037.73	53.00	Cost Plus	Canadian Longyear
BC-6	1775.8	12,937.76	7.29	2,806.49	1.58	19,429.10	10.94	2,738.53	1.54	37,911.88	21.35	Do.	Do.
BC-7	1525.2	18,229.63	11.95	14,611.24	9.58	37,855.44	24.82	11,724.97	7.69	82,421.28	54.04	Do.	Do.
Totals	7426.0	#43,029.89	#10.86	#22,496.17	#5.68	#72,087.54	#18.19	#17,757.29	#4.48	251,551.44	33.87		

*Subject to correction since not all accounting complete on BC-5, and credit for equipment purchased on Longyear contract and supplies on hand not determined.

#Using footage and cost for Canadian Longyear Drilling only

Contractor	Total Cost	Total Footage Drilled	Total Cost Per Foot $
L. Whatley	25,075.94	572.5	43.80
Core Drilling	71,104.61	2,891.4	24.59
Longyear	155,370.89	3,962.1	39.21
Total	251,551.44	7,426.0	33.87

COAL BEDS

Coal beds vary from those that are continuous along the outcrop for 10 miles or more to small lenses that have only a local extent. The occurrence of coal or carbonaceous material on top of the Basal Kootenay sandstone appears to be present throughout the Crowsnest coal basin, since this relationship was observed on all well-exposed outcrops. This basal bed is the most persistent bed observed in the coal measures. It appears that the lateral extent of individual coal beds decreases upward from the Basal Kootenay sandstone. This is particularly true of beds M-10 and M-9 along the outcrop on Morrissey Ridge, where both of these beds thin, in places, to less than five feet. The upper beds on Flathead Ridge are also lenticular, and although more work is required to evaluate their potential, data obtained to date are not favorable (see Map 6L-166).

The coal beds are thickest in the lower part of the Kootenay formation, where thicknesses are in excess of 50 feet. Although coal from beds near the top of the section are relatively thin, they contain the best coking coal.

The correlation charts, 6L-161, 162, and 166, illustrate the lenticular nature of the coal beds, and the sandstone and shale units. This relationship indicates extremely variable conditions during the deposition of the sediments overlying the Basal Kootenay sandstone. Because the coal beds and shales weather easily and are difficult to map in the field, correlation is based largely on sandstones. The lenticular nature of the sandstones, however, limits their usefulness as marker beds. The Basal Kootenay sandstone is an excellent marker horizon.

Because of their lenticular nature and the difficulty of correlating even within limited areas, the coal beds are numbered for specific areas only. The prefix of the bed number refers to the area of location, such as M for Morrissey Ridge, FE for Fernie Ridge, etc. In numbering the beds, an attempt has been made to be consistent with numbers used by Crow's Nest Pass Coal Company in mine workings of the upper beds at the inactive Elk River Colliery in Coal Creek (between Fernie and Morrissey Ridges).

Correlation charts of Fernie and Flathead Ridges have been tied to extreme ends of the correlation chart of Morrissey Ridge for convenience in reviewing each area. No attempt, however, should be made to try to correlate any one coal bed from the north end of Fernie Ridge to the south end of Flathead Ridge. There are large distance gaps in both Coal Creek and Morrissey Creek areas.

There are two types of ash within the coal beds; that which is part of the coal itself and often referred to as inherent ash, and that which is in the form of partings. Normally the latter is easily distinguished from inherent ash, but in the lower coal beds where deformation has ground, rolled and intermixed the rock partings with the coal, there is little distinction between the two. Geologists were not always able to distinguish clean coal from dirty coal, dirty coal from bone, and bone from carbonaceous shale. Descriptions of sample units were often changed from coal to bone after analyses were received. The ash content, as well as the thickness of each coal bed, is graphically illustrated along strike on Charts 6C-540 and 541, and show the highly variable nature of the ash content.

The ash content of raw coal from adit samples collected in 1960 and 1961 ranged from 44.0 to 7.7 percent on Morrissey Ridge and from 40.7 to 9.4 percent on Fernie Ridge. Weighted averages of ash content for adit samples are 22.8 percent for Morrissey Ridge (19 samples), and 23.7 percent for Fernie Ridge (11 samples). Two samples from the Balmer Mine averaged 16.6 percent ash.

Ash residues from proximate analyses of trench samples on Fernie and Morrissey Ridges and from core samples in hole BC-2 were obtained and plotted on the drill log and correlation charts to determine if color of the ash could be used in correlation of the coal beds. It was found that there is no distinctive color for any of the coal beds, and so this procedure is of no assistance.

All coal beds have relatively low sulfur contents. Most of the samples contained from 0.30 to 0.60 percent sulfur, and it is rare for the sulfur to exceed 1.00 percent.

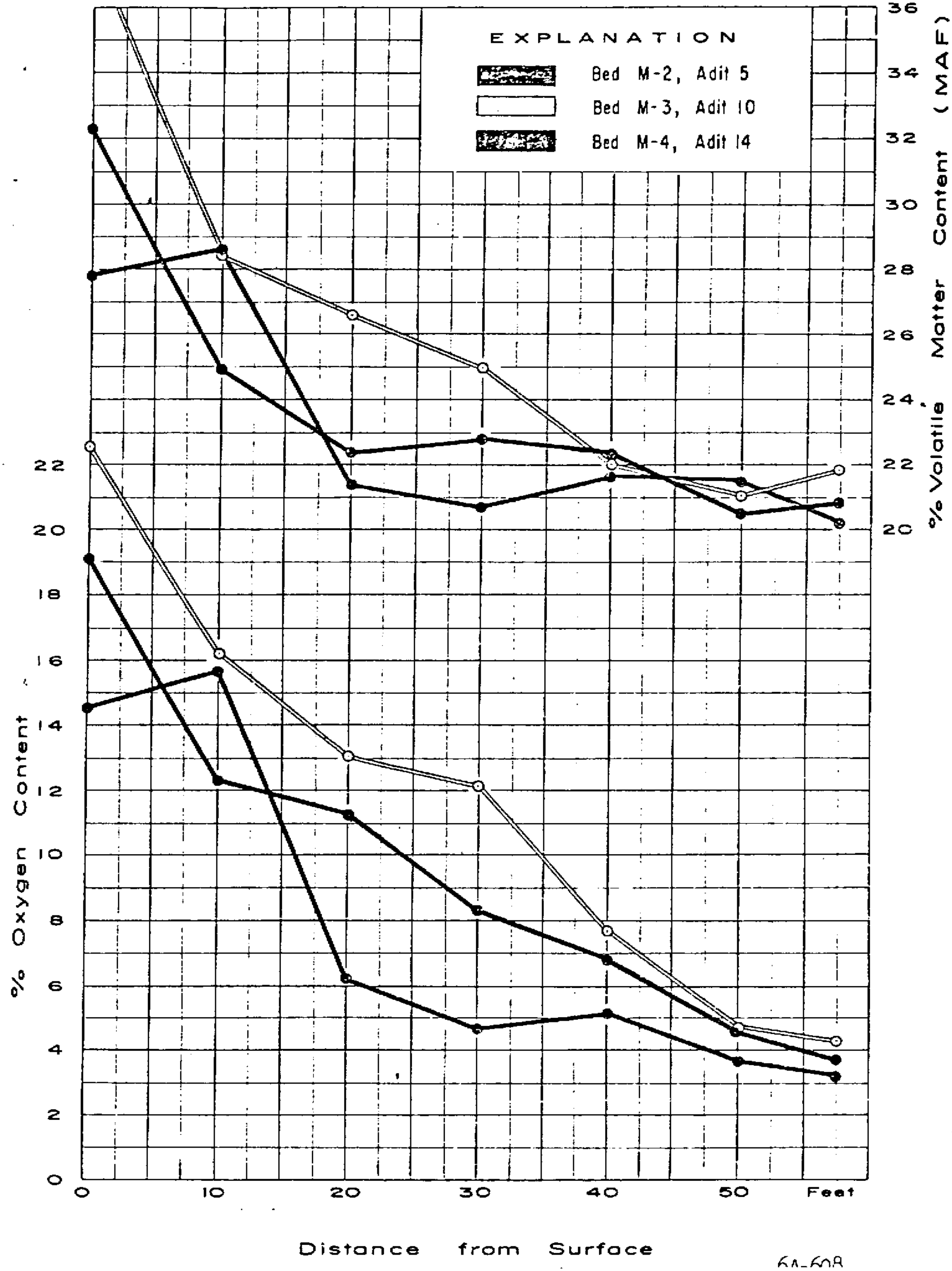
The physical condition of the coal in each bed on Fernie and Morrissey Ridges is described in Tables VIII and IX. Although the physical condition is highly variable, the coal generally is more friable in the lower beds which have been subjected to the most severe deformation. Near the top of the coal measures the coal tends to be less disturbed, is harder and brighter, and exhibits a more distinct cleating pattern. The color photograph of bed M-9, Figure 15, where it was exposed at the drill site of hole BC-2, shows a physical appearance that is typical of some of the upper coal beds.

The coal beds are graphically illustrated, in detail at 1"= 10', in the measured sections (see Maps 6M-422 through 452).

Change in Oxygen and Volatile Matter Content

ADITS 5, 10, and 14.

CROPCO'61 PROJECT



6A-608

COAL QUALITY

Rank

All Cropco coals are considered medium- and low-volatile bituminous in rank. Petrographic analyses of samples taken in 1960 and processed by the Applied Research Laboratory, Monroeville, confirmed this ranking. By the A.S.T.M. classification, some analyses of outcrop samples for the upper coal beds exceed the limit of volatile matter for medium-volatile coal, but this is attributed to surface oxidation.

At any one location, there is a range in volatile matter content of approximately 10 percentage points from the basal bed to the upper bed. Near the middle of Morrissey Ridge, this range in volatile matter content is from about 18 to 28 percent, whereas on Fernie Ridge the range is from about 20 to 30 percent, for washed samples from adits.

There is a decrease in volatile matter in coal beds drilled down dip from the outcrops of Morrissey Ridge. On the outcrop in adit 3 the volatile matter content of bed M-9 is 25 percent; in hole BC-1 the V.M. for the same bed is 23 percent, and in holes BC-5 and BC-6, both farther down dip, the V.M. has dropped to 17 percent. In the Coal Company diamond drill bore-hole 5, drilled on the south side of Coal Creek, the V.M. of bed M-9 is also 17 percent. This change in V.M. is not due to variable ash content. The ash content of the samples noted above varies from 8 to 18 percent, and one analysis from hole BC-5 has 16 percent V.M. with 8 percent ash.

The down-dip change in rank from a medium-volatile to a low-volatile coal also changes the coking characteristics of the coal. The FSI of samples for bed M-9 on the outcrop and in hole BC-1 varies from 8 to 9. In hole BC-6 the FSI of bed M-9 drops to 4 and is only 1 in hole BC-5. The low V.M. and FSI of bed M-9 in hole BC-5 may be due to poor core recovery, but there is enough evidence to support down-dip changes in rank and quality.

Oxidation

Results of tests by the Applied Research Laboratory indicated that the samples taken in 1960 from the basal coal beds on Morrissey Ridge were oxidized. It was suggested that the samples may have been taken from the zone of surface oxidation or that they were partially oxidized during transport and storage. Investigation was undertaken during 1961 to determine if the former was true.

Channel samples were taken from the side of the adits in three coal beds (M-2, M-3, and M-4) at intervals of 10 feet from the surface, and a fresh sample was taken from the face of each adit. Both petrographic and chemical analyses showed a decrease in oxygen content from the surface to the end of the adits. The oxygen and volatile matter content of these samples were plotted against the distance from the surface, as shown on Chart 6A-608. Both the volatile matter and oxygen content leveled off, which indicates that the ends of the adits are beyond the effects of surface oxidation. The irregularities are attributed to analytical deviations. The distance an adit should be driven before taking a bulk sample was determined as outlined above, that is, when the volatile matter content leveled off and the FSI was the same for two or three sample intervals, the bulk samples were taken.

If hole BC-2 had not been drilled, the question of whether or not the adits were driven beyond the surface oxidation zone might have remained unanswered, but analyses of the lower beds in hole BC-2, at hole depths in excess of 800 feet, are comparable to analyses obtained from the bulk samples taken from the adits. The oxygen content of the bulk samples is generally lower than the oxygen content of the drill hole samples for the same bed. The FSI (free-swelling index) is in the same order for both types of samples, with 2 as a high except for three samples from the drill hole. Some samples from both adits and the drill hole were non-agglomerating. From the data obtained from hole BC-2, it is assumed that the bulk samples did extend beyond the zone of surface oxidation and are representative of unweathered coal.

It follows, then, that the reason coals from the lower beds do not produce strong cokes is because they are oxidized beyond, and for reasons other than, normal surface oxidation. It is known that oxidation has extended to the point where the basal bed was cut in hole BC-2, at a depth of 1600 feet, and it probably extends deeper to points beyond economic cover limitations.

The number of beds affected by deep oxidation varies from area to area. Along Morrissey Ridge, available data indicate there is a marked change in the degree of cokability between beds M-4 and M-5. Coal from bed M-4 and beds lower in the section are either weakly coking or non-coking; whereas coal from bed M-5 and beds higher in the section are moderately- to strongly-coking. On Fernie Ridge, the change is higher in the section. Coal bed FE-8 did not produce coke. Bed FE-9 was not sampled during 1961 because of inclement weather late in the field season. Coal from the lower bench of bed FE-B, which was faulted and oxidized, did not produce coke, but the sample from the middle bench coked. At the north end of Sparwood Ridge, none of the coal beds appear to be oxidized. Samples from the Balmer mine, which is in the basal coal bed of the Kootenay formation, produced strong coke.

It has been observed in the field that the lower coal beds are more highly deformed than the upper beds. Folds in the basal Kootenay sandstone with several hundred feet of amplitude have not affected the upper part of the Kootenay formation. In areas of deformation, the coal has been crushed and intermixed with rock partings to become friable. There is a marked contrast between the hardness and physical condition of the coal in the Balmer Mine at the north end of Sparwood Ridge and coals in the basal beds on Morrissey Ridge. The reason for the variability of oxidation appears to be associated with the degree of deformation to which the coal has been subjected.

All the coal beds on the west side of the coal basin crop out high above the water table and, as discussed under Hydrology, serve as aquifers. The oxidation of coal beds, as it affects coking characteristics, is not dependent on the level of the ground water table in the coal beds. The lower coal beds in hole BC-2 could be below the water table. Bed M-1 in hole BC-2 is about 500 feet in elevation above the outcrop of the coal bed in Morrissey Creek, and the horizontal distance between the two points is 20,000 feet, or a gradient of 2.5 percent. This hole was drilled with mud, so the level of the water table was not determined, but the mud was thinned when coal beds were encountered. The fact also remains that the upper coal beds, which are higher on the structure and which should have natural water drainage, are not oxidized to the extent of affecting cokability in adits on the surface.

There appears to be a strong correlation between the degree of deformation and the degree of V.M. oxidation at Cropco. It is possible that the particle size of the coal is an indicator of the variation in oxidation, that is, oxidation is greatest where the particle size is smallest, and vice-versa.

Analytical Data

All the samples taken during 1960 were processed under the direction of the Corporation's Applied Research and Robena laboratories. Washability tests on nine 4- ton bulk samples were run by Commercial Testing and Engineering Company and Robena Laboratory. Carbonization data on these samples and analyses of drill core were furnished by Applied Research Laboratory.

During 1961, all sample processing was under the direction of Raw Materials Research Laboratory at Geneva, Utah. Samples were shipped directly to Colorado School of Mines Research Foundation, Golden, Colorado, where washability tests and chemical analyses were performed under contract. Washed samples were then shipped to Geneva for carbonization tests. The programing of tests was designed to provide all sample data by May 1, 1962, for inclusion in this report.

Trench Samples

A total of 502 channel samples were taken from trenches on 25 ridges along the west side of the coal basin. Proximate analyses were run on these samples, and these are posted on measured sections, correlation charts, and tables of coal beds. These samples were taken primarily to provide close control on ash content, which is shown graphically for each coal bed, by ridge, on Charts 6C-540 and 541. These samples being weathered, did not provide information on coking quality.

Drill Hole Samples

Samples breaks of coal in drill holes are shown on the drill hole logs. Proximate and ultimate analyses, which are also posted on the drill hole logs, were run on all samples.

Cuttings samples were collected in non-core drilling when there was any evidence that coal was being drilled. Many of the cuttings samples, therefore, contained more rock than coal, as indicated by analyses on the drill hole logs. To determine how much of each was in the samples, a heavy-media separation was made on all the cuttings samples at a gravity of 1.50. The percent float and the proximate analyses of the float are shown in Table X.

Adit Samples

All nine of the 4-ton bulk samples taken in 1960 were washed on six gravity breaks (from 1.30 to 1.75), and carbonization tests were run on the samples that were not oxidized.

In order to limit costs and speed up the processing of the samples, 100-pound face channel samples were taken from adits in 1961 for the purpose of running microwashing tests on four gravity breaks, from 1.35 to 1.65. After reviewing the results of a representative number of the microwashing tests, it was determined that bulk samples, whose channel samples would give a yield greater than 70 percent and an ash content less than 10 percent at specific gravity 1.55,

Table X

Drill Hole Cuttings
Heavy-Media Separation
1.50 Gravity
Cropco Project

Sample No.	Float % Weight	V.M.	F.C.	Ash	S	FSI 1"x10M	FSI 10Mx0
BC3-1	8.17	22.72	64.85	12.43	0.52	6*	8
BC3-2	5.28	23.88	64.74	11.38	0.65	2*	9
BC3-3	5.10	23.90	61.86	14.24	0.64	8*	9
BC3-4	5.51	28.82	63.53	7.65	0.75	3½*	9
BC3-5	3.22	26.12	66.04	7.84	0.74	9	9
BC3-6	5.49	23.68	61.82	14.49	0.26	4*	9
BC3-7	1.82	25.16	65.43	9.41	0.93	3*	9
BC3-8	1.28	24.01	65.41	10.56	0.83	7*	9
BC3-9	0.57	26.33	62.43	11.24	-	4*	9
10	2.61	24.10	61.81	14.10	0.73	5*	9
11	33.08	23.48	63.52	12.99	0.59	9	9
12	19.15	22.73	65.33	11.95	0.55	3½	9
13	9.68	24.09	62.64	13.26	0.63	9	9
14	92.29	24.01	65.36	10.64	0.58	9	9
15	36.32	26.16	63.30	10.54	0.56	9	9
16	34.28	23.74	64.60	11.66	0.54	9	9
17	23.32	22.37	66.25	11.38	0.52	9	9
18	17.35	23.33	65.62	11.04	0.53	9	8½
19	11.88	23.32	65.50	11.18	0.51	8½	9
20	17.20	22.49	65.32	12.18	0.50	5	9
21	22.93	23.35	65.95	10.70	0.52	9	9
22	22.07	23.11	66.29	10.59	0.53	9	9
23	14.29	22.75	64.86	12.39	0.51	9	9
24	23.32	22.91	66.03	11.05	0.59	9	9
25	36.89	22.44	64.76	12.79	0.53	9	9
26	36.54	23.74	66.95	9.30	0.53	8½	9
27	55.96	23.13	66.63	10.24	0.55	8	9
28	38.57	23.30	67.08	9.62	0.62	8½	9
29	34.15	23.04	67.56	9.40	0.62	9	9
30	21.51	22.89	68.23	8.87	0.54	9	9
BC4-1	53.07	24.78	64.56	10.66	0.68	9	9
BC5-1	82.57	20.45	67.86	11.69	0.74	6½	6
2	26.09	20.50	67.56	11.97	0.75	6½	7½
3**	6.31	21.42	72.46	6.12	0.78	-	7
4	81.81	21.41	71.32	7.25	0.61	6	7½
5	68.58	20.89	70.03	9.07	0.72	7½	7½
6	13.60	21.43	71.18	7.39	0.85	7½	8
7**	9.50	23.48	69.21	7.30	0.96	-	9
8	0.80	21.01	72.03	6.97	0.87	6	7½
9	0.34	21.24	66.20	12.56	0.93	6	8½
10	53.83	20.79	70.69	8.51	0.47	8	9
11	39.20	21.63	70.68	7.68	0.54	7½	9

Table X (con't)

Sample No.	% Weight	V.M.	F.C.	Ash	S	FSI 1"x10M	FSI 10M x 0
BC5-12	40.70	23.85	67.63	8.53	0.50	8	9
BC5-13	85.69	22.73	69.64	7.63	0.38	7	8½
14	90.40	22.36	70.18	7.46	0.36	7½	9
15	84.52	21.12	71.79	7.09	0.38	7½	9
16	69.13	21.61	70.07	8.32	0.40	8	9
17**	41.18	21.35	72.14	6.51	0.47		9
18**	27.90	21.08	71.75	7.16	0.43		8
19	42.45	21.31	69.75	8.94	0.42	4½	8½
20**	34.41	21.55	71.88	6.57	0.45		8
21	71.39	21.05	70.74	8.21	0.39	7½	9

*Estimated

** Sample reject (60 mesh)

should be washed. Based on these criteria, 14 of the 28 bulk samples qualified for bulk washing. Some samples that were border line were also washed, but in each case the washed product had an ash content in excess of 10 percent. One set of samples (adit 21, channel sample 1, and bulk sample 19-3) showed a raw coal ash content less than that of the washed coal, but this is attributed to a discrepancy in sampling.

Washability curves were prepared to evaluate each sample and these are included in the map pocket. Microwashing, bulk washing, and analytical data are shown in Tables XI and XII.

On Morrissey Ridge, there are only two beds that consistently washed clean. Bed M-9 gave yields of 85 to 93 percent with ash contents of 3.8 to 8.2 percent, and Bed M-5 gave yields of 85 and 86 percent with ash contents of 6.1 to 8.0 percent. Beds M-1, M-2, and M-3 are generally borderline cases since they gave average yield of about 70 percent at about 10 percent ash. Bed M-10 is exceptionally dirty on the outcrop where adit samples were taken, and yields on two samples were 45 and 64 percent with ash contents of 8.6 percent and 9.4 percent, respectively.

On Fernie Ridge, bed FE-B washed to 5.8 percent ash at a 77 percent yield; bed FE-8 washed to 8.5 percent ash at a 69 percent yield, and bed FE-1 (lower bench) washed to 13.5 percent ash at a 71 percent yield. Bed FE-9 was not sampled because of inclement weather. Yields of the other beds sampled are below 70 percent, as indicated in the tables.

Carbonization Tests

Results of carbonization tests presented in Tables XI and XII show that the coals sampled vary from non-coking to strongly coking. Samples which produced strong coke were taken from coal beds in the upper part of the Kootenay formation, whereas coals that were non-coking to weakly-coking were taken from coal beds in the lower part of the formation. As indicated earlier, the major factor affecting the coke strength is degree of oxidation.

Coal that produced the strongest coke was obtained from bed M-9, and coke strength was maintained in blends using up to 30 percent Corbin, Lundale, and Wellington coals. Coals from bed M-10 also produced strong coke, but the yield on the washed product (one bulk sample) was only 45 percent. Coal from beds M-5 and M-6 produced fairly strong cokes. The only sample from Fernie Ridge that coked was taken from bed FE-B. Bed FE-9 was not sampled, but is believed to be coking. Coals from the Balmer Mine (basal Kootenay) produced fairly strong coke. The remaining samples were poorly or non-coking coals.

There is a marked difference in coking pressures between the carbonization tests reported by Applied Research Laboratory and Raw Materials Research Laboratory. By using samples from bed M-9 as a common reference, the difference is about 5 to 1, with the pressures reported by Applied Research being the highest. Personnel of the Geneva Research Laboratory were unable to explain this discrepancy, stating that the tests were run in the same type of ovens and with calibrated instruments. All results valid. Stabilities of >60 ≈ FST of 6½!

Excessive coking pressures were exerted by samples from beds M-10, M-6, M-5 and the Balmer Mine and the use of these coals will require blending with non-coking or high-volatile coals to reduce coking pressures to safe operating levels for conventional steel-industry by-product coke ovens. Coking pressures of the other coals could be controlled by varying bulk densities.

ESTIMATED RESERVES

Estimated reserves presented herein are of a lower magnitude than any of several previous estimates because they are limited to coking coals only. Quality data were not available for previous estimates, which were not limited to coking coals.

Reserves estimated for Option A are concentrated in areas along and behind Fernie and Morrissey Ridges (see Maps 6C-532 and 536). There are other areas within the property held under Option A which may contain potential coking coal reserves, but estimates were not made for these areas because of insufficient control data. Such areas are more difficult of access, are more highly disturbed and will require drilling and other detailed work to obtain necessary information on structure, cover and coal quality.

Estimated reserves under Option A between the Provincial Government block on Fernie Ridge and the Dominion Government block which borders Morrissey Creek, total 142 million tons of recoverable raw coking coals, or 113 million tons of washed coking coals, under 2,500 feet of cover.

Calculations of estimated reserves were based on the following rules:

1. Because mining methods vary with the dip of the coal beds, reserves were calculated and tabulated in the following increments:

   <u>Dip Increments</u>

   0-15 degrees
   15-30 "
   30-60 "

2. Maximum thickness (mining height)

Dip	Thickness
0-30 degrees	12 feet
30-90 "	Full best bench and to top of bed, provided rock partings over 2 feet are not taken.

3. Minimum thickness (mining height)

   5 feet

4. Minimum thickness of rock interval between beds

Cover	Rock Interval
Less than 2,000 feet	30 feet
Greater than 2,000 feet	50 feet

5. Maximum thickness of rock parting included

   2 feet

6. Maximum rock partings included

   10 percent of bed thickness

7. Maximum ash contents

   Raw coal - 25 percent

   Washed coal - 10 percent

8. Minimum yield for washed coal

   70 percent

9. Depth of cover increments

   0-1,500 feet

   1,500-2,000 feet

   2,000-2,500 feet

10. Free swelling index

    Minimum of (1) button

11. Conversion factors used in reserve estimation

    Coal in place - 1,800 tons per acre-foot

    Recoverable raw coal - 900 tons per acre-foot

    Washed coal - as determined by test work

Cross sections prepared served as a basis for controlling structure contours. The same datum, the base of the Basal Elk conglomerate, was used for determining limits of cover on beds M-10 and M-9 on Morrissey Ridge, and beds FE-B and FE-9 on Fernie Ridge. As bed M-5 is about 600 feet below the Elk formation, separate contours were prepared for determining the limits of this bed. Depth of cover contours were also determined for each of these beds, as shown on Maps 6C-532 and 536.

Estimated reserves are combined into one classification, measured and indicated. The following definition of indicated reserves by the U.S.G.S. applies:

> "Indicated reserves of coal are reserves for which tonnage is computed partly from specific measurements and partly from projection of visible data for a reasonable distance on geologic evidence. In general, the points of observation are approximately one mile apart, but they may be as much as one and a half miles apart for beds of known geologic continuity."

Reserves were estimated only for coal beds which are known to contain good coking coal; namely, beds FE-B, FE-9, M-10, M-9, and M-5. Other beds that coked were either too dirty to qualify under the above set of rules, or were of minor areal extent. Bed FE-9 was not sampled because of inclement weather late in the field season, but it is assumed to contain coking coal because of its stratigraphic position and known coking quality at the south end of Fernie Ridge. The washed coal yield is low on bed M-10, where it was sampled on the outcrop, and most of the data used for computing reserves were obtained from drill holes and old mine workings.

The reserves are tabulated in Table XIII by property, bed number, area, vertical cover, and dip of beds. The outline of the area used to compute the reserves of each bed is shown on Maps 6C-533 through 536.

Table XIV gives a percentage distribution of reserves by dip increments, for 0-1500 feet and 0-2500 feet of cover. Nearly half of reserves under 0-1500 feet of cover have dips in 30 to 60 degree range; whereas, for 0-2500 feet of cover nearly half of reserves are in the 0-15 degree range.

TABLE XIV

PERCENTAGE DISTRIBUTION OF RESERVES BY DIP INCREMENTS

Percentage of Total Recoverable Raw Coal Reserves			
Dip of Beds (in degrees)	Remarks	0-1500 Ft. of Cover	0-2500 Ft. of Cover
0 - 15	Best for conventional equipment, Low-cost mining.	18	49
15 - 30	Difficult mining. Need specialized equipment.	31	30
30 - 60	Gravity used to advantage in breaking and moving coal.	51	21
All		100	100
Total Net Tons Raw Recoverable		49 million	142 million

MINING CONSIDERATIONS

Structure

It is generally understood and agreed by mining personnel that coal beds dipping less than 15 degrees can be mined effectively by modern heavy-duty mining equipment, particularly continuous miners and shuttle cars, but this equipment does not operate effectively in beds dipping greater than 15 degrees. Gravity is usually used to move coal in beds that dip more than 30 degrees. Coal beds dipping between 15 and 30 degrees fall into a problem area where the pitch is too steep to maneuver heavy equipment and too flat for the coal to run by gravity. As indicated in the geologic cross sections and the tabulated reserves, a considerable portion (approximately 30%) of the coking coal reserves is contained in beds that dip between 15 and 30 degrees. It is difficult to arrive at reliable mining costs for these dips because of lack of historical data, but it is assumed that mining costs will be higher than for either flatter or steeper dips.

Displacement of coal beds by faulting always complicates mining operations and thereby increases costs. No attempt was made to map all the faults in the potential mining areas, which would require large-scale detailed mapping, but it is likely that faults do exist because they have been encountered in the mines at Michel and Coal Creek.

The tight folding which occurs along the outcrop near the basal part of the Kootenay formation gives rise to serious mining problems, and the areas so deformed would present difficult underground mining conditions. Since these folds tend to die out near the upper part of the Kootenay formation, it is possible that other folds may occur down dip from the outcrop without being expressed on the surface.

Cover

The bulk of potential reserves of high quality coking coal under Option A occurs in areas where the cover approaches 2,000 feet. Although old mine workings at Coal Creek extend under cover that is in excess of 2,000 feet difficulty was experienced with severe bumps and bursts. Mining personnel of Crow's Nest Pass Coal Company have verbally indicated that bumps and bursts, can become serious when cover exceeds 1,500 feet.

Roof and Floor Conditions

In most Cropco coal beds, the transition of coal to rock is not a sharp break, but is rather a gradational change from coal to bone, bone to carbonaceous shale, and carbonaceous shale to shale. Often, bone and carbonaceous shale are interbedded with thin coal partings. There are exceptions, however, where coal is overlain by firm shale, sandstone, or conglomerate.

The relative condition of the roof and floor of each coal bed at each measured section location is indicated in Tables VIII and IX, where the condition is classified as good, fair, and poor. A roof and floor is classified as good when there is a sharp break from the coal bed to a carbonaceous-free rock, as poor when the carbonaceous zone between the coal bed and the firm rock is more than five feet thick, and as fair when conditions are between these extremes. Most of the roof and floor classifications are poor.

Information obtained from drilling operations indicates that the highly carbonaceous rocks will be difficult to control in mining operations. There was no caving of clean rock types in any of the drill holes, but several of the holes were stopped because of caving carbonaceous rocks. The ash content of the material that caved was as high as 60 percent.

Roof and floor conditions in general improve from the lower coal beds to the upper coal beds. There are two reasons for this: 1) there has been more deformation in the lower part of the coal measures, which has broken the rocks near the coal beds, and 2) the transition zone of coal to rock is thicker in the lower beds.

In some areas where thick coal beds occur, such as at Somerset, "top coal" is left as a roof. Because of the friable nature of the coal, it is doubtful that this practice could be applied to the thick coal beds at Cropco.

Water and Gas

Crowsnest coal basin is also a ground water basin. Mining operations which extend below natural surface water drainage will require water pumping facilities.

In past mining operations at both Michel and Coal Creek, gas has not presented any problems that could not be solved. Newmarch, however states that in 1909 "violent outbursts of gas" forced the abandonment of mines along Morrissey Creek.

Holes drilled well back from the edge of the basin encountered water with a gas drive. These holes include hole BC-6, behind the old mine workings in Morrissey Creek, and holes BC-3, BC-5, and BC-7 in the Coal Creek drainage. The gas so encountered is probably associated with the coal beds, and probably does not occur in amounts excessive for mining.

Low-Cost Mining

There are large reserves of coal mostly non-coking and high ash, in the many beds which outcrop along Morrissey and Fernie Ridges. It has been suggested that all types of low-cost mining be investigated to determine if these coals can be exploited as economical sources of carbon. Auger and hydraulic mining are currently being investigated, and it is tentatively planned to have experts in these fields visit the project in June 1962 for the purpose of appraising the applicability of such methods; however, dips are adverse for augering.

Apparently, the hardness of coal is a factor in both auger and hydraulic mining, but this should not be a problem with most Cropco coals, particularly the lower beds. Some of the coals are so friable that they may be difficult to control by either of these mining methods. Where beds have not been crushed, rock partings will be a factor to consider.

ADIT AND SAMPLE DATA

CROPCO PROJECT
1961

Adit No.	Location	Length* (Ft.)	Man Shifts	Bulk Sample No.	Net Weight (Lbs.)	Face (100 Lb.) Channel Sample No.	Coal Bed
2	Morrissey Ridge 10	42	24	12	[illegible]	385 Top 386 387 388 Base 389 Composite	M-1 U
10	Morrissey Ridge 10	72	42	13	7534	377 Top 378 379 Base 380 Composite	M-3
13	Coal Creek	[illegible]	37	11	[illegible]	[illegible]	[illegible]
14	Morrissey Ridge 15	79	34	14	8574	374 Top 375 Base 376 Composite	M-4
15	Morrissey Ridge 15	124	65	17	8552	381 Top 382 383 Base 384 Composite	M-2
16	Morrissey Ridge 15	112	57	16	8274	390 Top 391 392 Base 393 Composite	M-1 U
17	Morrissey Ridge 0	53	30	15	[illegible]	395	M-1 L
18	Morrissey Ridge 0	55	22	13	8596	396	M-2
19	Fernie Ridge 10	36	[illegible]	25-2 25-1	3892 [illegible]	398 Top 397 Base	FE-1
				19-1	[illegible]	399	

21	Ridge 20			19-3	[illegible]	4 Composite	
22	Fernie Ridge 10	60	31	25	81-1	23	FE-
23	Fernie Ridge 10	60	2[illegible]	21	811[illegible]	21	FE
24	Morrissey Ridge 13	84	41	20-1 20-2	8[illegible]4 8727	17 Top 18 Base	M-
25	Morrissey Ridge 18	81	36	22	8379	16	M-
26	Fernie Ridge 10	57	24	24	9043	22	FE
27	Morrissey Ridge 19	50	32	Encountered Fault - No Sample Taken			M-
28	Morrissey Ridge 18	63	28	26	8265	15	
29	Fernie Ridge 10	75	39	Faulted Coal Oxidized - Not Shipped	-	51	
30	Fernie Ridge 10	71	41	29	8532	44	
31	Fernie Ridge 10	118	62	32-3 32-2 32-1	4681 3714 3741	50 Top 49 48 Base	
32	Morrissey Ridge 14	54	25	27	8106	34	
33	Morrissey Ridge 14	52	26	31	8547	35	
34	Morrissey Ridge 4	70	35	30	8934	52	
35	Morrissey Ridge 4	53	45	23	8736	53	
TOTALS:				[illegible]	20[illegible].011	45	

Bed Number	Year Sampled	Adit No.	Adit Ridge Loc	Channel Sample No.	Channel Sample Thick.	Raw Coal VM	Raw Coal FC	Raw Coal Ash	Raw Coal S	Raw Coal O_2	Raw Coal FSI	Microwashing Results (1.55 Grvity) Yield	Microwashing Ash	Bulk Washing Sample No	Bulk Washing Sample Thick	Washed Coal Yield	Washed Coal VM	Washed Coal FC	Washed Coal Ash	Washed Coal S	Washed Coal C	Washed Coal H_2	Washed Coal N_2	Washed Coal O_2	Washed Coal FSI	Plastometer I.S.T.	Plastometer M.F.T.	Plastometer D.D.	Plastometer S.T.	Laboratory
M-10	1960	11	M-10	*		19.2	*	38.1	0.63	*	*	*	*	9	4.9	45	27.1	*	8.6	0.84	*	*	*	*	8	384	455	340	490	ARL
	1961	33	M-14	35	7.9	20.5	54.5	25.0	0.52	3.97	8-8½	64	[illegible].4	31	7.9	Not washed														GRL
M-9	1960	3	M-9	*		25.2	*	7.7	0.60	*	*	*	*	1	14.3	93	25.8	*	3.8	0.45	*	*	*	*	8	384	457	96	493	ARL
	1961	32	M-14	34	11.5	24.5	63.6	11.9	0.64	4.87	8½	90	7.1	27	11.5	85	22.0	69.8	8.2	0.56	80.6	4.6	1.0	5.0	8½	381	459	87	492	GRL
	1961	35	M-4	53	5.9	27.8	64.3	7.9	0.60	5.08	9	97	6.4	28	5.9	85	28.1	65.9	6.0	0.56	82.3	5.2	1.2	4.7	9	375	456	400	495	GRL
M-6	1960	6	M-9	*		23.3	*	15.2	0.54	*	*	*	*	2	15.9	83	23.7	*	6.8	0.49	*	*	*	*	6½	403	455	3.5	434	ARL
	1961	28	M-18	15	7.2	15.0	41.0	44.0	0.59	3.76	3	51	7.7	26	7.2	Not washed														GRL
	1961	34	M-4	52	13.1	20.8	48.7	30.5	0.32	5.01	6	55	7.9	30	13.1	Not washed														GRL
M-5 (?)	1960	7	M-9	*		18.5	*	37.1	0.36	*	*	*	*	3	20.7	52	24.6	*	4.9	0.51	*	*	*	*	6½	407	459	4.5	456	ARL
M-5U	1960	8	M-9	*		20.3	*	15.2	0.60	*	*	*	*	6	13.0	85	21.3	*	8.0	0.56	*	*	*	*	2	432	456	0.7	486	ARL
M-5	1960	9	M-9	*		18.8	*	15.9	0.54	*	*	*	*	3	15.1	85	20.1		7.6	0.55	*	*	*	*	3	421	460	1.1	490	ARL
(Upper bench)	1961	24	M-18	17	6.1	19.0	64.1	16.9	0.58	4.45	6-6½	79	[illegible].6	20-1	6.1	36	18.3	75.1	6.1	0.65	83.2	4.5	1.4	4.2	2 (6½)	441	474	0.8	492	GRL
(Lower bench)	1961	24	M-18	18	13.8	15.9	44.2	39.9	0.35	2.80	1	38	[illegible].2	20-2	13.3	Not washed														GRL
M-4	1961	14	M-15	376	24.0	17.2	53.1	24.7	0.48	5.61	Ag	72	[illegible].7	14	24.0	74	16.7	72.5	10.8	0.53	77.8	4.2	1.3	5.4	1	Non-fluid				GRL
	1961	25	M-18	16	9.3	14.8	56.0	29.2	0.54	4.13	1	67	[illegible].3	22	9.3	Not washed														GRL
M-3	1961	10	M-10	380	52.9	17.6	62.3	20.1	0.43	4.30	Ag	74	[illegible]	13	52.9	72	17.6	71.7	10.7	0.38	73.8	4.2	1.2	4.7	1	Non-fluid				GRL
M-2 (Upper bench)	1960	5	M-10	*		17.7	*	14.3	0.46	*	*	*	*	5	15.9	85	18.2	*	7.7	0.46	*	*	*	*	1	468	471	0.1	477	ARL
(Lower bench)	1960	5	M-10	*		16.9	*	25.5	0.45	*	*	*	*	4	13.1	66	13.3		8.6	0.50	*	*	*	*	2½	433	453	0.5	436	ARL
	1961	15	M-15	384	35.2	14.3	49.8	35.9	0.50	4.02	Ag	72	[illegible].9	17	35.2	Not washed														GRL
	1961	18	M-0	396	6.4	17.0	63.1	19.9	0.58	5.13	1	73	[illegible].3	13	6.4	79	13.1	70.5	11.4	0.67	78.5	4.1	1.0	4.3	1	Non-fluid				GRL
M-1U (Upper bench)	1961	2	M-10	389	23.0	17.7	66.3	16.0	0.34	4.33	NA	86	[illegible].1	12	23.0	83	18.0	72.8	9.2	0.36	81.1	4.3	1.2	3.8	1	Non-fluid				GRL
(Lower bench)	1960	2	M-10	*		17.1	*	17.8	0.26	*	*	*	*	7	32.7	81	17.9	*	9.9	0.29	*	*	*	*	1	Non-fluid				ARL
	1961	16	M-15	393	40.7	15.6	68.4	16.0	0.30	4.78	NA	85	[illegible].5	16	40.7	76	16.5	74.0	9.5	0.34	81.0	4.2	1.1	3.9	1	Non-fluid				GRL
M-1 (Upper bench)	1961	21	M-20	399	26.7	14.1	58.3	27.6	0.45	4.70	Ag	66	13.6	19-1	26.7	Not washed														GRL
(Middle bench)	1961	21	M-20	400	8.0	16.6	68.6	14.8	0.47	3.76	1½-2	89	[illegible].5	19-2	8.0	73	14.8	72.5	12.7	0.50	78.3	4.0	1.2	3.3	1	Non-fluid				GRL
(Lower bench)	1961	21	M-20	1	15.3	16.6	72.4	11.0	0.50	8.24	2	87	9.7	19-3	15.3	64	15.5	71.6	12.9	0.51	77.8	4.0	1.2	3.6	1	441	465	1.0	495	GRL
(Composite) ←	1961	21	M-20	4	53.5	15.6	63.9	20.5	0.50	4.05	1½	75	13.2	-	53.5	Not washed														GRL
M-1L	1961	17	M-0	395	12.5	19.0	56.0	25.0	0.53	4.44	Ag	64	[illegible].7	15	12.5	Not washed														GRL

Carbonization Tests – Washed Coal

Bed	Blend	500-lb. Oven Pressure	Stability	Hardness	+1" Seive	30-lb.-Oven Pressure	Sole Oven % Expansion	Sole Oven % Contraction
M-10	100% No. 9	3.7	63	70	92	*	*	*
	50% No. 9, 50% Wellington	2.0	63	73	92			
	50% No. 9, 50% Corbin	1.5	63	72	94			
	50% No. 9, 50% Lundale	2.1	62	71	95			
M-9	100% No. 1	2.5	63	71	94	*	*	*
	70% No. 1, 30% Wellington	2.7	63	72	95			
	70% No. 1, 30% Corbin	2.0	62	72	95			
	70% No. 1, 30% Lundale	1.9	58	71	96			
	100% No. 27	0.42	51	66	96	1.39	0	4.4
	90% No. 27, 10% H.V.	0.51	55	69	96	0.71	0	4.2
	80% No. 27, 20% H.V.	0.37	52	67	96	0.66	0	2.9
	70% No. 27, 30% H.V.	0.40	54	67	95	0.65	0	3.3
	100% No. 28	0.46	55	68	95	1.40	0	0.4
	90% No. 28, 10% H.V.	0.63	60	70	96	0.68	*	*
	80% No. 28, 20% H.V.	0.52	59	71	96	0.45	*	*
	70% No. 28, 30% H.V.	0.42	60	74	96	0.61	*	*
M-6	100% No. 2	3.4	65	70	84	*	*	*
	60% No. 2, 40% Wellington	1.7	60	68	86	*	*	*
	60% No. 2, 40% Corbin	2.1	65	73	92	*	*	*
	60% No. 2, 40% Lundale	2.5	66	72	92	*	*	*
M-5	100% No. 3	7.0	64	70	90	*	*	*
	40% No. 3, 60% Wellington	2.5	56	69	87	*	*	*
	40% No. 3, 60% Corbin	3.3	61	73	93	*	*	*
	40% No. 3, 60% Lundale	2.3	61	70	96	*	*	*
	100% No. 6	2.5	22	29	30	*	*	*
	80% No. 6, 20% Corbin	2.1	34	47	60	*	*	*
	80% No. 6, 20% Lundale	1.4	59	65	88	*	*	*
	100% No. 8	3.2	47	53	69	*	*	*
	70% No. 8, 30% Wellington	1.7	44	54	74	*	*	*
	70% No. 8, 30% Corbin	1.3	58	66	88	*	*	*
	70% No. 8, 30% Lundale	2.2	64	73	92	*	*	*
	100% No. 20-1	5.48	56	63	77	Off scale	16.3	0
	Excessive pressure - no blends tested							
M-4	100% No. 14	0.29	No coke produced		2	1.21	0	6.9
M-3	100% No. 13	0.29	No coke produced		3	0.22	0	15.6
M-2	100% No. 5		No coke produced					
	100% No. 4		No coke produced					
	80% No. 18, 20% H.V.	0.38	No coke produced		10	0.52	0	9.45
M-1U	100% No. 12	0.30	No coke produced		-	0.33	0	11.65
	100% No. 7		No coke produced					
	100% No. 16	0.41	No coke produced		2	0.35	0	10.2
M-1	100% No. 19-2	0.77	No coke produced		9	2.96	0	5.25
	100% No. 19-3	0.46	25	33	62	12.84	0	2.55
	90% 19-3, 10% H.V.	0.37	13	28	36	5.33	0	4.20

*Data not obtained.

(18)

ADIT SAMPLE DATA
CROPCO PROJECT
MORRISSEY RIDGE

ADIT SAMPLE DATA
CROPCO PROJECT

BED NUMBER	YEAR SAMPLED	ADIT		CHANNEL SAMPLE		ANALYSES (RAW COAL)						MICROWASHING RESULTS (1.55 GRAVITY)		BULK WASHING RESULTS - 1.55 GRAVITY: SAMPLE		ANALYSES - WASHED COAL										PLASTOMETER					TESTS - WASHED COAL: 500 - LB. OVEN			30-LB. OVEN PRESSURE	SOLE OVEN		LABORATORY
		NO.	RIDGE LOC.	NO.	THICK	VM	FC	ASH	S	O_2	F.S.I.	YIELD	ASH	NO.	THICK.	YIELD	VM	FC	ASH	S	C	H_2	N_2	O_2	FSI	I.S.T.	M.F.T.	D.D.	S.T.		STABILITY	HARDNESS	+1" SEIVE		% EXPANSION	% CONTRACTION	
FERNIE RIDGE																																					
FE-B																																					
(Upper bench)	1961	31	Fe-10	50	18.7	20.3	39.0	40.7	0.41	5.87	1	48	8.6	32-3	18.7	Not washed																					
(Middle bench)	1961	31	Fe-10	49	11.7	31.[illegible]	58.7	9.4	0.46	7.98	7-7½	94	4.2	32-2	11.7	77	30.4 32.2	63.8	5.8	0.46	79.4	5.0	1.3	8.0	3	372	453	10.4	480	100% 32-2	43	56	93	0.80	*	*	GRL
																														90% 32-2,	32	50	89	0.33			
																														80% 32-2,	33	45	90	0.18			
(Lower bench)	1961	31	do.	48	7.2	29.3	54.7	15.5	0.36	10.29	NA	80	4.0	32-1	7.2	72	31.0	63.9	5.1	0.37	77.5	4.7	1.3	11.0	NA	Non-fluid				100% 32-1	No coke produced		0	0.58	0	22.5	GRL
	1961	13	Coal Creek	394	10.9	19.3	41.6	38.6	0.42	3.65	Ag	52	5.9	11	10.9	Not washed									OX												GRL
FE-8	1961	30	Fe-10	44	22.4	23.[illegible]	56.8	19.3	0.35	8.75	1	77	5.1	29	22.4	69	27.2 29.5	64.3	8.	0.38	75.8	4.5	1.3	9.5	1	414	444	0.3	474	100% 29	No coke produced			0.18	0	18.3	GRL
FE-7	1961	29	do.	51	19.4	23.[illegible]	50.9	25.2	0.36	12.31	NA	73	5.9	Sample not shipped - Coal is faulted and xidized																							GRL
FE-5	1961	23	do.	21	10.4	18.[illegible]	55.6	25.9	0.47	5.24	1	52	11.2	21	10.4	Not washed																					GRL
FE-4	1961	26	do.	22	8.9	18.3	49.8	31.9	0.59	5.13	1	58	9.7	24	8.9	Not washed																					GRL
FE-2	1961	22	do.	23	26.1	15.[illegible]	44.6	40.3	0.55	4.59	1	51	12.6	23	26.1	Not washed																					GRL
FE-1																																					
(Upper bench)	1961	19	do.	398	14.0	20.[illegible]	56.9	23.1	0.50	6.53	Ag	68	11.8	25-2	14.0	Not washed																					GRL
(Lower bench)	1961	19	do.	397	15.0	18.5	59.0	22.5	0.53	5.33	Ag	78	11.8	25-1	15.0	71	19.6 23.2	66.9	13.[illegible]	0.53	74.8	4.1	1.0	6.1	1	393	459	0.5	483	100% 25-1	5 ok	23	23	0.41	0	9.3	GRL
																														90% 25-1,	9	25	28	0.68	0	10.1	
																														80% 25-1,	12	27	36	*	*	*	
																														70% 25-1,	15	29	44	*	*	*	
BALMER MINE MICHEL COLLIERY																																					
Basal	1960			*		17.3	*	16.3	0.35	*	*	*	*	10	61.6	85	18.0	*	9.[illegible]	0.33	*	*	*	*	6½	430	472	2.5	499	100% No. 1	-	-	-	*	*	*	ARL
																														70% No. 1C	50	61	86	*	*	*	
																														70% No. 1C	60	72	90	*	*	*	
do. (500 lb.)	1961				61.6	16.[illegible]	66.2	16.9	0.30	3.28	4½-5	83	9.6	10-61	61.6	80	Data not available													70% No. 1C	64	72	95	*	*	*	

*Data not obtained.