MOUNT KLAPPAN COAL PROJECT
LOST - FOX AREA
GEOLOGICAL REPORT
1984

APPENDIX III

1983 ADIT DATA

709

Gulf

GULF CANADA RESOURCES INC.

COAL DIVISION

GULF CANADA RESOURCES INC.

MOUNT KLAPPAN BULK SAMPLE PROGRAM

1983

PART I PROCEDURES

PART II COAL QUALITY

CONFIDENTIAL COAL ANALYSIS DATA REMOVED

GULF CANADA RESOURCES INC.

MARCH, 1984

MT. KLAPPAN ADIT REPORT PART I

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MT. KLAPPAN 1983 BULK SAMPLE PROGRAM

1.0 INTRODUCTION

1.1 Exploration Framework

The Mount Klappan Coal Property is located in northwestern British Columbia, some 336 kilometers northeast of Prince Rupert. The licences lie at the northern end of the Bowser Basin, just north of the Groundhog coalfield, and cover coal-bearing strata of Upper Jurassic to Lower Cretaceous age.

To date Gulf Canada Resources Inc. has conducted three years of exploration on the property which has resulted in the identification of two large areas of open-pit mine potential, (see Figure 1.1).

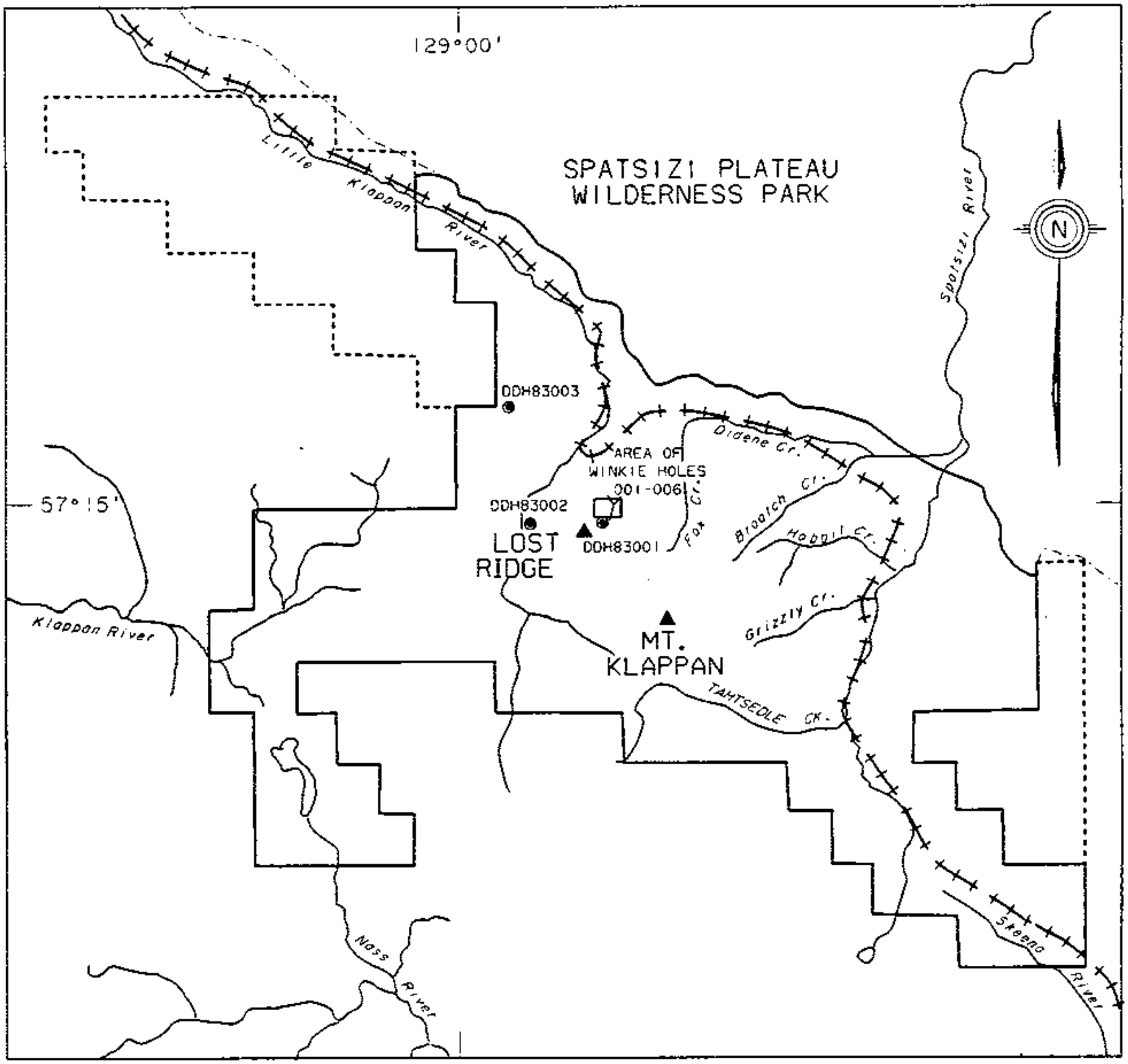
A bulk sampling program was undertaken in one of these areas on Lost Ridge during the period September 2nd to October 14th, 1983. A total of 39.24 tonnes of coal were taken from Seam I: 37.19 tonnes formed the bulk sample while the remaining 2.05 tonnes comprised various channel samples. The precise objectives of the bulk sampling program, which formed part of a much wider exploration effort, are discussed below in Section 1.2.

The data included in the following report is concerned solely with the bulk sampling program; Part I deals with logistics, monitoring, supervision and data collection processes while Part

FIGURE 1.1

MT. KLAPPAN COAL PROPERTY

LOCATION MAP



LEGEND

- PREPARED RAIL BED
- PROVINCIAL PARK BOUNDARY
- HQ DIAMOND DRILL HOLE - 1983
- AQX WINKIE HOLES - 1983 001-006
- ADIT 1983
- LICENCE AREA
- LICENCES UNDER APPLICATION

SCALE

0 1 2 3 4 5 km

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15/03/84

II presents the technical data derived from the various samples that were taken.

1.2 Program Objectives

The three primary objectives of the 1983 Mount Klappan bulk sample program were as follows:

1) To provide information on the natural size distribution of anthracite from seam I in a mining situation.
2) To provide a sufficiently large and representative sample for a comprehensive analysis of a variety of sized coals in raw and cleaned states.
3) To provide material for sample product distribution to a number of potential customers.

Care was taken that sufficient material was extracted at the sample point both to provide for full representation of the seam and for all the samples for which requests had been received.

2.0 Logistics

2.1 Introduction

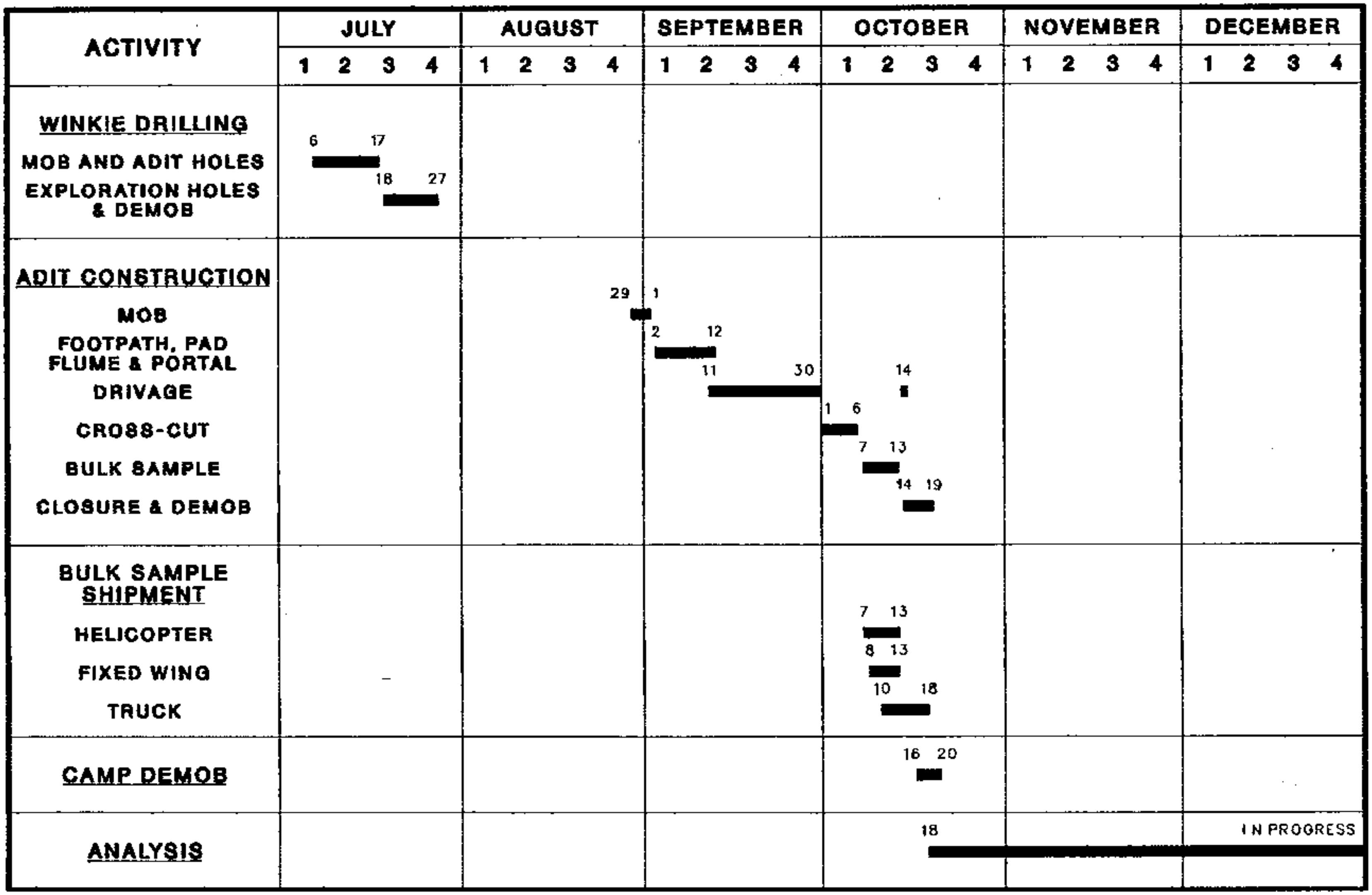
The bulk sample program consisted of two phases; phase I was a small drilling program followed by phase II, the actual adit construction. The entire program was spread over 14 weeks with a 5 week break between phase I and phase II. A schedule of events relating to the bulk sampling program is presented in Figure 2.1.

Prior to the final adit site selection it was necessary to determine whether an acceptable sample could be obtained from the bulk sample point. To this end a series of holes were drilled on Lost Ridge which were designed to penetrate only Seam I. The drilling was carried out using a light-weight, small core diameter Winkie drill (see Section 2.2). Core obtained from the drilling was described in detail, sampled and sent to Calgary for analysis.

The results of the core sample analyses (presented in Part II) confirmed the location of the adit and once final approval had been granted, adit construction began. Details of the procedures used in adit construction are discussed in Section 4.0 while further information about the contractor and equipment is presented below in Section 2.3.

As access to the Property, during 1982, was by air only, all support of the Winkie drilling and adit construction was by helicopter. A Hughes 500D was used to move the drill crew, adit crew and geologists. This helicopter also moved the Winkie drill equipment and most of the equipment and supplies for the adit.

FIGURE 2.1
SCHEDULE OF EVENTS: BULK SAMPLE PROGRAM, 1983



A1190A
A1190A1

Three heavy pieces of equipment, the compressor, generator and tugger were lifted from the airstrip to the top of Lost Ridge by a Bell 205. This machine was also used to demobilize equipment at the end of the program.

Mobilization of adit equipment and supplies was from Dease Lake using a DeHavilland Caribou and from Smithers using a Beechcraft 18 and a Norman Britten Islander. Bulk sample transport was by Hughes 500D from the adit to the Summit airstrip, by fixed wing to the nearest truck accessible airstrip (at Burrage Creek) and then by truck to Calgary.

Camp facilities for phase I were provided by Gulf Canada while phase II required the additional facilities of a second camp. This camp, located at the airstrip, had earlier been used to house a diamond drill crew who had been contracted for the general exploration program. The camp was leased from the drilling contractor and run by Gulf. Camp demobilization was mainly via Hughes 500D to the Burrage airstrip on Highway 37 and then by truck to Smithers.

2.2 Winkie Drilling

The contractor for the Winkie drilling was Teck Corporation of Vancouver, British Columbia. This equipment was operated by 2 men on a 12 hour shift and produced AIX sized core from a hole of approximately 3.5 centimetres in diameter. The support equipment is listed below:

1) Drill Stem = 100 metres
2) Casing = 20 metres
3) Waterpumps = 2
4) Mudtanks = 2 - 200 gallons each
5) Waterline = 500 metres

No geophysical logs were run down the drill holes.

2.3 Adit

The contractor for the adit construction was Target Tunnelling of Strathmore, Alberta. The drill crew comprised five qualified underground miners and two surface laborers. A list of the equipment used in the construction of the adit is provided below.

1) Air Compressor
2) Tugger (winch) and Cable
3) Generator
4) Pneumatic Picks
5) Miscellaneous Shovels, Picks and Augers
6) Explosives Magazines - (3)

Plus supplies of sheet metal ducting for the flume, logs, planks and explosives.

2.4 Project Management and Primary Contractors

Geological services and supervision of field operations for the adit drivage and bulk sampling were provided by JHP Coal-Ex Consulting Ltd. The program was carried out under the supervision of B. P. Flynn, and assistance in the field was provided by J. W. Innis.

The supervision of the Winkie drill portion of the program and the collection of data from the drill core was conducted by Gulf Canada personnel under the direction of C. S. Williams.

The personnel and primary contractors who contributed to the 1983 Mt. Klappan Bulk Sampling Program are listed below:

Gulf Personnel

B. P. Flynn	Project Supervisor
C. S. Williams	Project Geologist
J. W. Innis	Senior Geologist
P. Tsavalos	Accountant

Consultant

John H. Perry	JHP Coal-Ex Consulting Ltd.

Contracting Companies

Target Tunneling	Adit Construction
Teck Corporation	Winkie Drilling
Glacier Helicopters	Helicopter Support
Northern Mountain Helicopters	Helicopter Support
Aero Expediting	Expediting Services
Central Mountain Air Services	Fixed Wing Support and Coal Haulage
Kelowna Flight Craft	Fixed Wing Support
Smithers Transport	Truck Coal Haulage
Cyclone Engineering Sales	Coal Analysis
Birtley Coal & Mineral Testing	Coal Analysis
David E. Pearson and Assoc.	Petrography

3.0 GEOLOGY

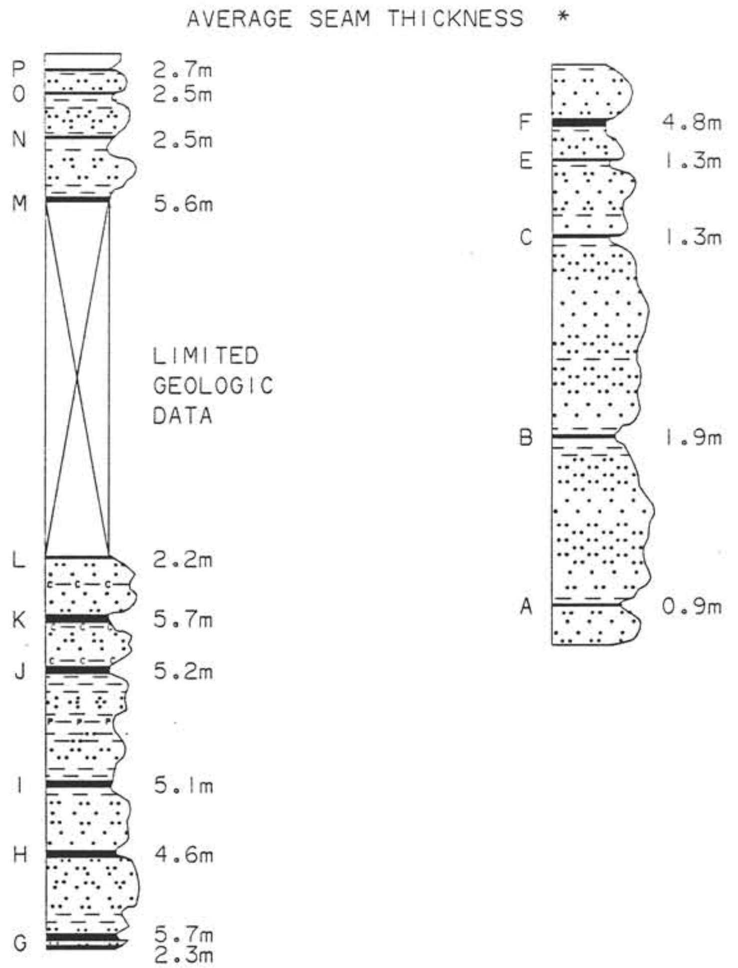
3.1 Stratigraphy of Lost Ridge

The Lost Ridge area is underlain by rocks of the Middle Klappan Unit of the Klappan Sequence. The precise age of these strata is, as yet, undetermined but they are generally considered to lie within the Upper Jurassic to Lower Cretaceous. This unit consists of a series of coarsening upward sequences of fine to medium grained sandstone, occasional conglomerate, siltstone, claystone and coal. It contains all the major coal seams that have been identified within the property which, in the Lost Ridge area, includes 12 coal seams greater than 0.50 meters in thickness. These seams have a cumulative average thickness of 24.3 meters over a 350 meter stratigraphic interval. The general stratigraphy of the Middle Klappan Unit in the Lost Ridge area is illustrated in Table 3.1.

TABLE 3.1

MT. KLAPPAN COAL PROPERTY

LOST-FOX AREA COAL SEAM DISTRIBUTION



* INCLUDES SEAM INTERSECTIONS >0.5m

SCALE: 1:5000

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3.2 Structure of Lost Ridge

The structure of Lost Ridge is dominated by a large southeasterly plunging anticline - syncline pair, (the Lost Ridge anticline, syncline). These folds are overturned to the northeast and are cut by a series of steep, southwest dipping thrust faults (see Figures 3.1 and 3.2).

The folds are characterized by long, gently dipping southwesterly limbs and shorter but steeply dipping overturned, vertical or right-way-up northeast limbs.

A second phase of folding is present, the trend of which is roughly east-west. This second phase manifests itself as regular changes and/or reversals in plunge along the axes of the primary phase folds. The effects of this second fold phase are not evident on Lost Ridge.

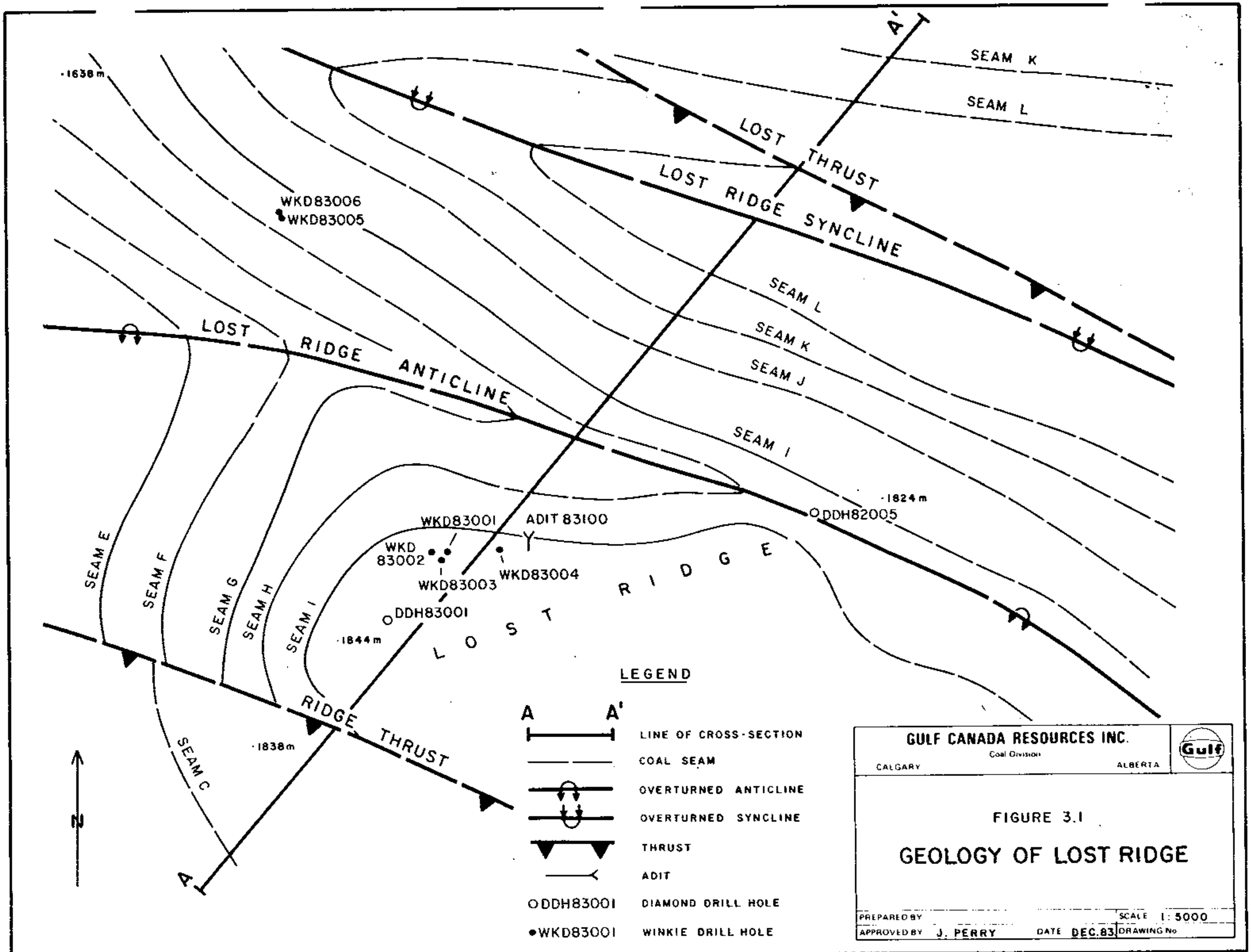


FIGURE 3.1
GEOLOGY OF LOST RIDGE

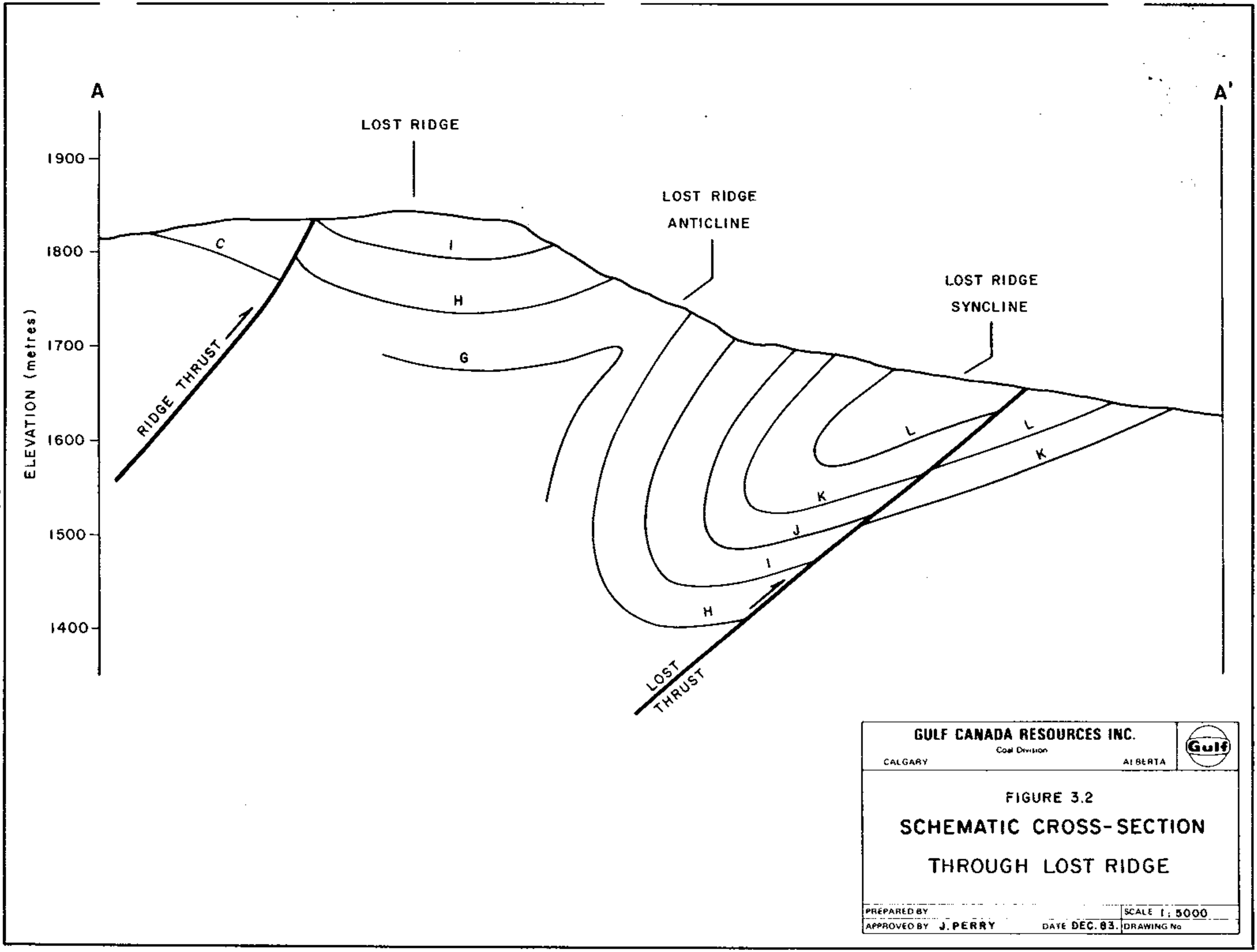


FIGURE 3.2

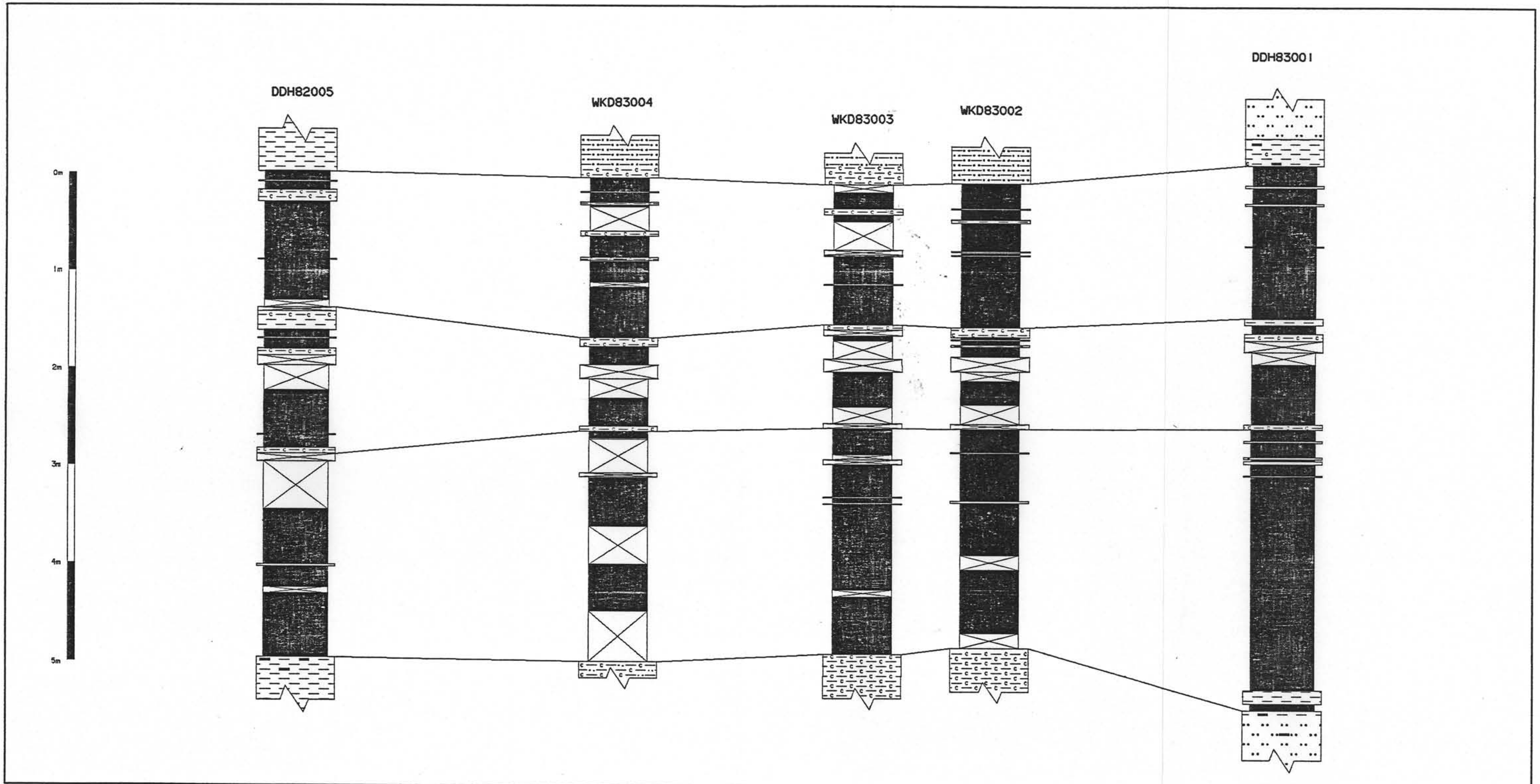
SCHEMATIC CROSS-SECTION THROUGH LOST RIDGE

3.3 Stratigraphy of Seam I

Prior to construction of the adit the most reliable data concerning Seam I in the Lost Ridge area came from two diamond drill holes, DDH 82005 and DDH 83001. This data was supplemented by three Winkie hole intersections (WDH 83002, 3 and 4), and a number of hand trenches dug during the 1982 and 1983 exploration programs.

Columnar sections of the Seam I intersections from holes DDH 82005 and DDH 83001 are presented in Figure 3.3. Seam thicknesses are 4.98 metres (DDH 82005) and 5.54 metres (DDH 83001). The latter may, however, have been subject to some structural thickening. Rock bands vary up to 0.20 metres in thickness and are generally restricted to the upper half of the seam.

More detailed discussion of the seam stratigraphy is presented in Section 5.4.



[205,57]831024100.LOC

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MT. KLAPPAN COAL PROPERTY
CORRELATION OF
SEAM I PROFILES

FIGURE 3.3

DRAWN BY:	SCALE: 1:40
APPROVED BY:	DATE: MAR 1984

4.0 ADIT CONSTRUCTION

4.1 Site Selection

Several sites were initially considered for the 1983 bulk sampling program, all of which lie on the northern slopes of Lost Ridge (see Figure 4.1). The major factors which determined the final site selection were:

i) Access
ii) Ease of site construction
iii) Rate of increase in depth of cover vs. length of driveage
iv) Proximity to suitable areas for waste coal disposal
v) Geological control of seam stratigraphy

The adit site selected optimized all of these factors and was presented for permitting and approval. During the time needed to receive the permits several Winkie holes (WKD 83002, 3 and 4, see Figure 3.1) were drilled in the proposed bulk sample area to test the level of oxidation, thickness and quality of the seam. The results from the drilling indicated that an acceptable sample could be obtained from this location. Two Winkie holes (WKD 83005 and 6) were drilled at a second site to provide an alternative if the primary site proved unsuitable or was not approved.

Once government approval for the primary site had been received construction of the adit began.

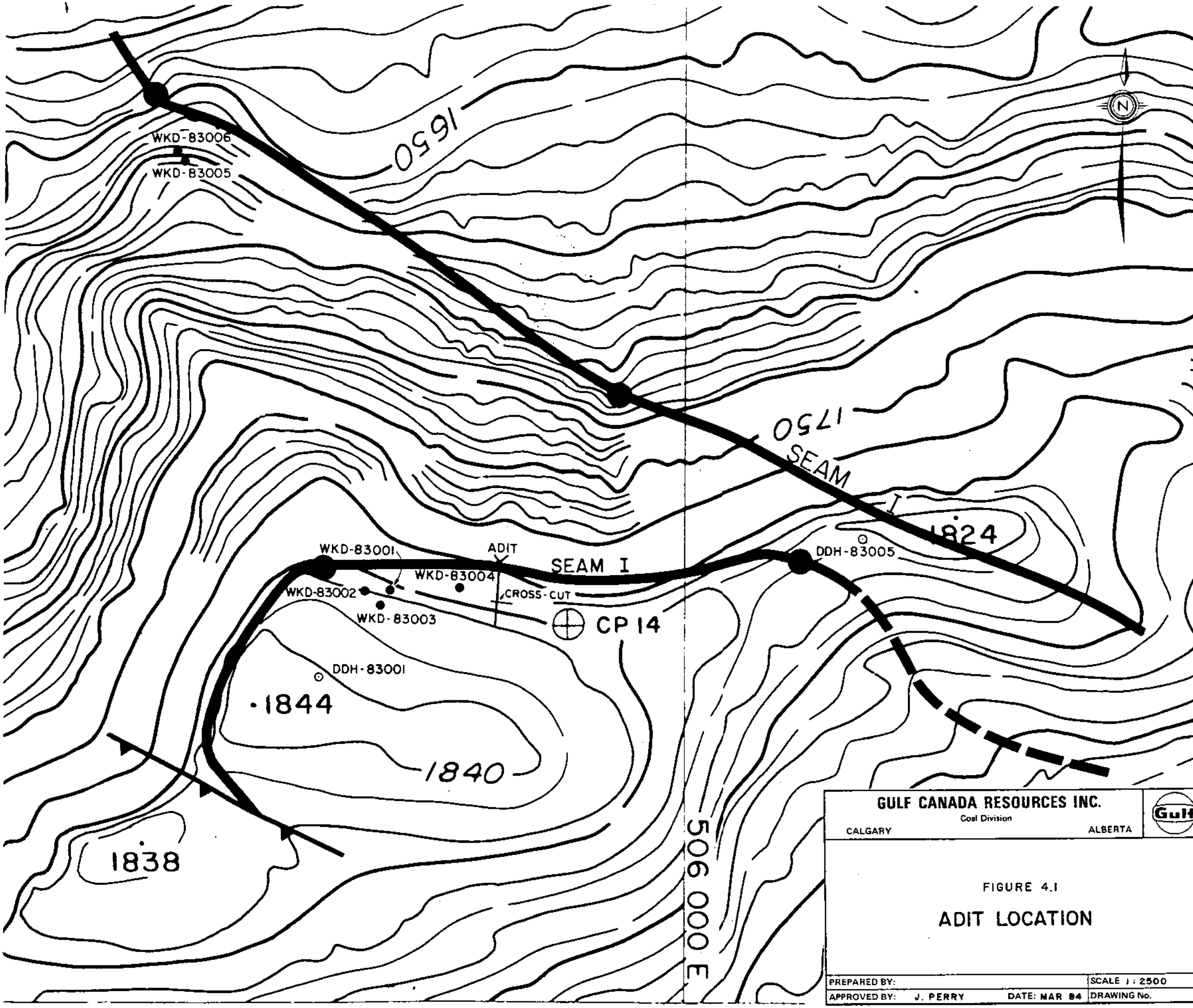


FIGURE 4.1

ADIT LOCATION

4.2 Regulatory Approvals

Application to conduct a bulk sampling program on the Mt. Klappan property was made to the British Columbia Ministry of Energy, Mines and Petroleum Resources in April, 1983. Several site visits were conducted during June, July and August by Gulf and Government personnel to assess the adit location, access and waste coal disposal proceedures. Final approval was granted in August, 1983.

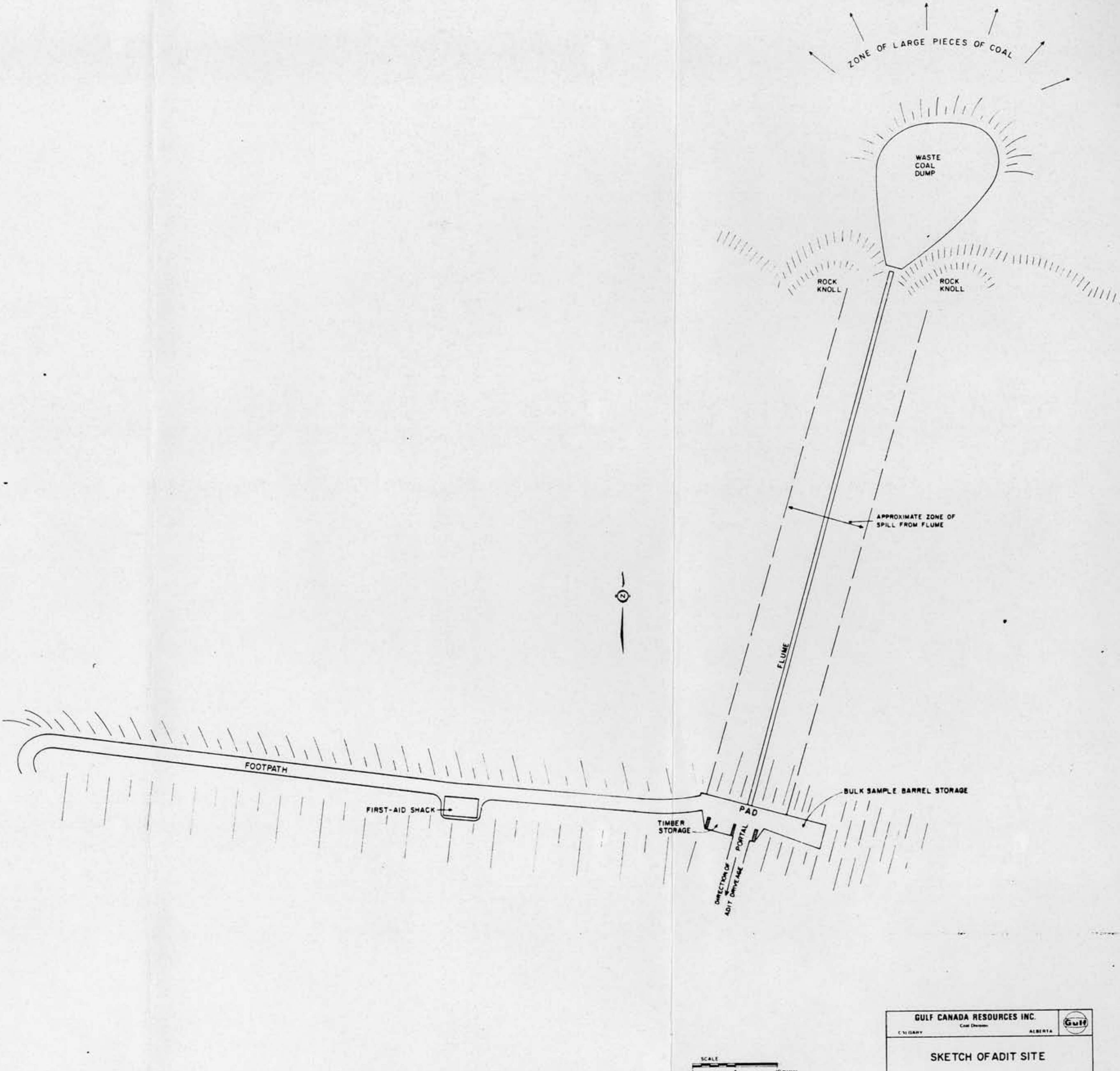
4.3 Site Preparation

Preparation of the adit site commenced on September 2, 1983 and was completed on September 9, 1982. All work was carried out by hand using shovels, picks and pneumatic drills.

A diagram illustrating the layout of the site is presented in Figure 4.2. As the adit was located part-way down a steep slope it was necessary to build a footpath from the top of Lost Ridge to the portal area. A pad was constructed at the adit site to provide a safe, flat area on which to work and store materials. This pad, which measured 9 metres long x 4 metres wide, was constructed at the base of the seam. Material produced as a result of cutting into the mountain side was used to build up the outer edge of the pad. The resulting high wall, (3 metres in height), was braced and timbered to prevent sloughing and to protect personnel from possible rock fall from above.

A smaller pad was excavated some way up the path from the portal area to accomodate a first aid post/lunch room.

The area selected for waste coal disposal was a small, dry gully immediately down slope from the portal. A flume measuring 87 metres in length was built from the portal to the top of the gully (approximately 1778 metres elevation). Sheet metal central heating ducting was used for the flume. Sections measuring 3.66 metres x 0.60 metres x 0.25 metres (length, width and depth, respectively) were riveted together at the pad and lowered down the slope.



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Coal Division
CALGARY ALBERTA

Gulf

SKETCH OF ADIT SITE

FIG. 4.2

PREPARED BY	SCALE 1:200
APPROVED BY JOHN PERRY DATE DEC.5-83	DRAWING No

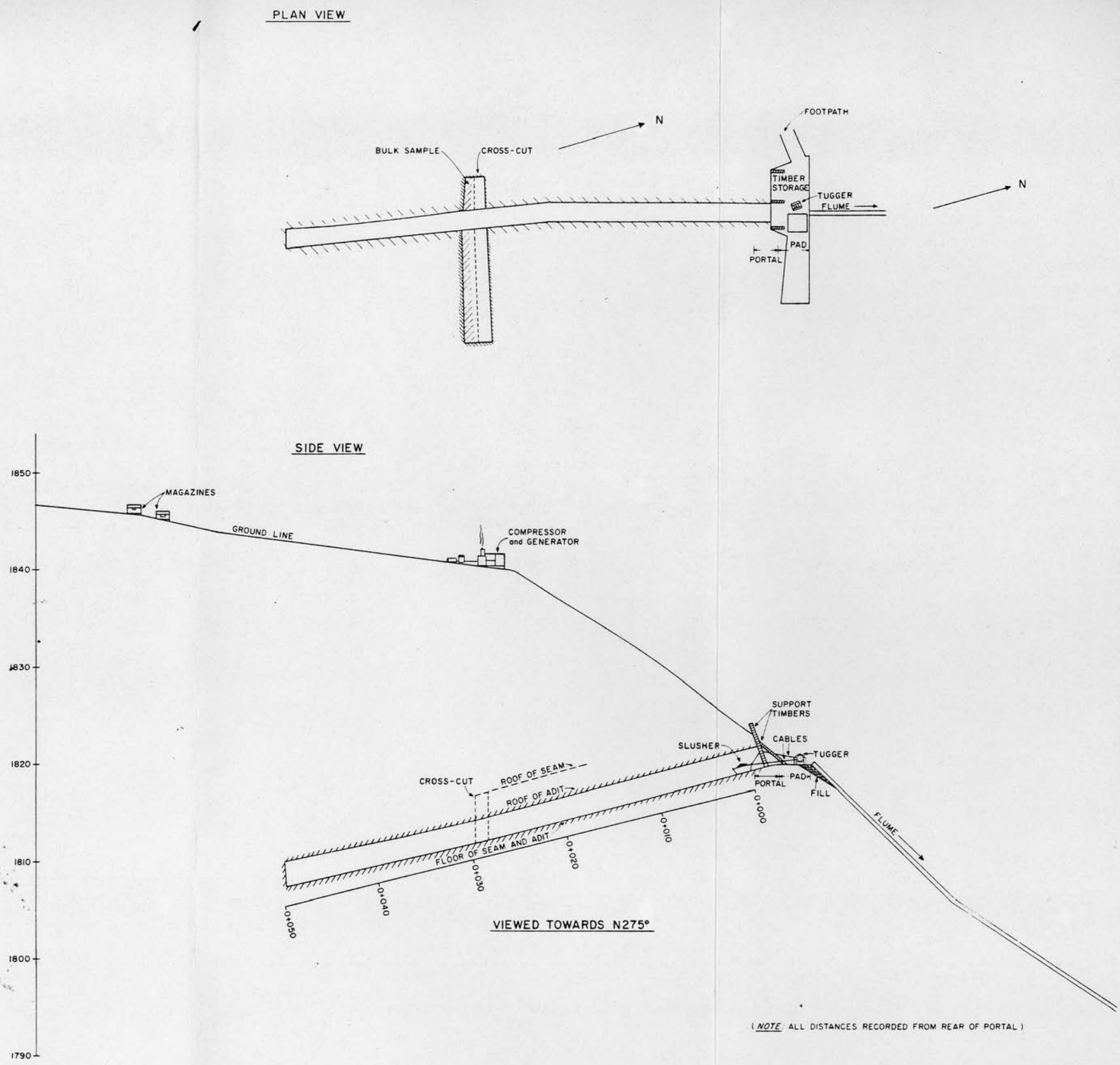
Once in position the flume was reinforced and braced at its lower end so that a slope sufficient to carry fine coal particles to the waste pile could be maintained. Installation of the flume commenced on September 10, 1983 and was completed by September 12, 1983.

Prior to taking the bulk sample the pad was extended to provide an area to store full sample barrels awaiting collection by the helicopter.

4.4 Adit Driveage

The underground portion of the bulk sample program consisted of driveage of an adit for a total of 50 metres and the extraction of approximately 39.24 tonnes of coal. Initially, it was planned that the adit be driven to 30 metres. However, due to concerns about the possible effects of permafrost on the size distribution of the sample, it was later decided to take the adit to 60 metres and then sample. A channel sample comprising four barrels was taken from the adit face at 30 metres and analyzed as the driveage continued. Deteriorating weather conditions forced a review of the timetable in late September. The results of size analysis of the channel sample were favourable and therefore, it was decided that the bulk sample would be taken at the 30 metre point and, subject to weather conditions, the adit would later be driven to 60 metres where a smaller bulk sample would be taken.

Drivage commenced on September 11th; the work was carried out on an 11 hour shift, seven days a week unless poor weather prevented access to the site. Advance of the adit face was achieved by drilling a series of 1.22 meter (4 foot) holes in the direction of driveage, and then blasting. Clearing of the face after blasting would usually provide an overall advance of approximately 1.5 metres. The waste coal was removed using a bucket and tugger, powered by compressed air. Upon removal of the waste the advance was timbered and lagged along the roof. As the sides of the adit exhibited little or no sloughing, no side wall lagging was necessary past the portal. Ventilation was supplied



SCALE

0 2.5 5 10 20 metres

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CALGARY ALBERTA
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PLAN VIEW AND CROSS-SECTION
OF ADIT DRIVEAGE
KPN-ADIT-83-100

FIG. 4.3

PREPARED BY		SCALE 1:200
APPROVED BY JOHN PERRY	DATE DEC 5-83	DRAWING No

by an air-mover and a 0.4 metre diameter cloth hose suspended along the wall of the adit and powered by a fan.

Apart from some surface run-off no water was encountered in the adit. The small amount of water that entered the adit through the portal was confined to one side of the tunnel and directed to an open joint in the floor approximately 2 metres inside the portal, down which it disappeared. Due to the hardness of the coal, very little dust was generated at the face and so no dust suppression procedures were necessary.

The adit was driven along the floor of the coal seam so that control could be exercised on the slope of the adit should the dip of the seam alter significantly under Lost Ridge.

The adit was not driven down the true dip of the seam and so the slope of the adit floor represents an apparent dip. The difference between the true dip direction and the adit driveage is approximately 25° to 30°.

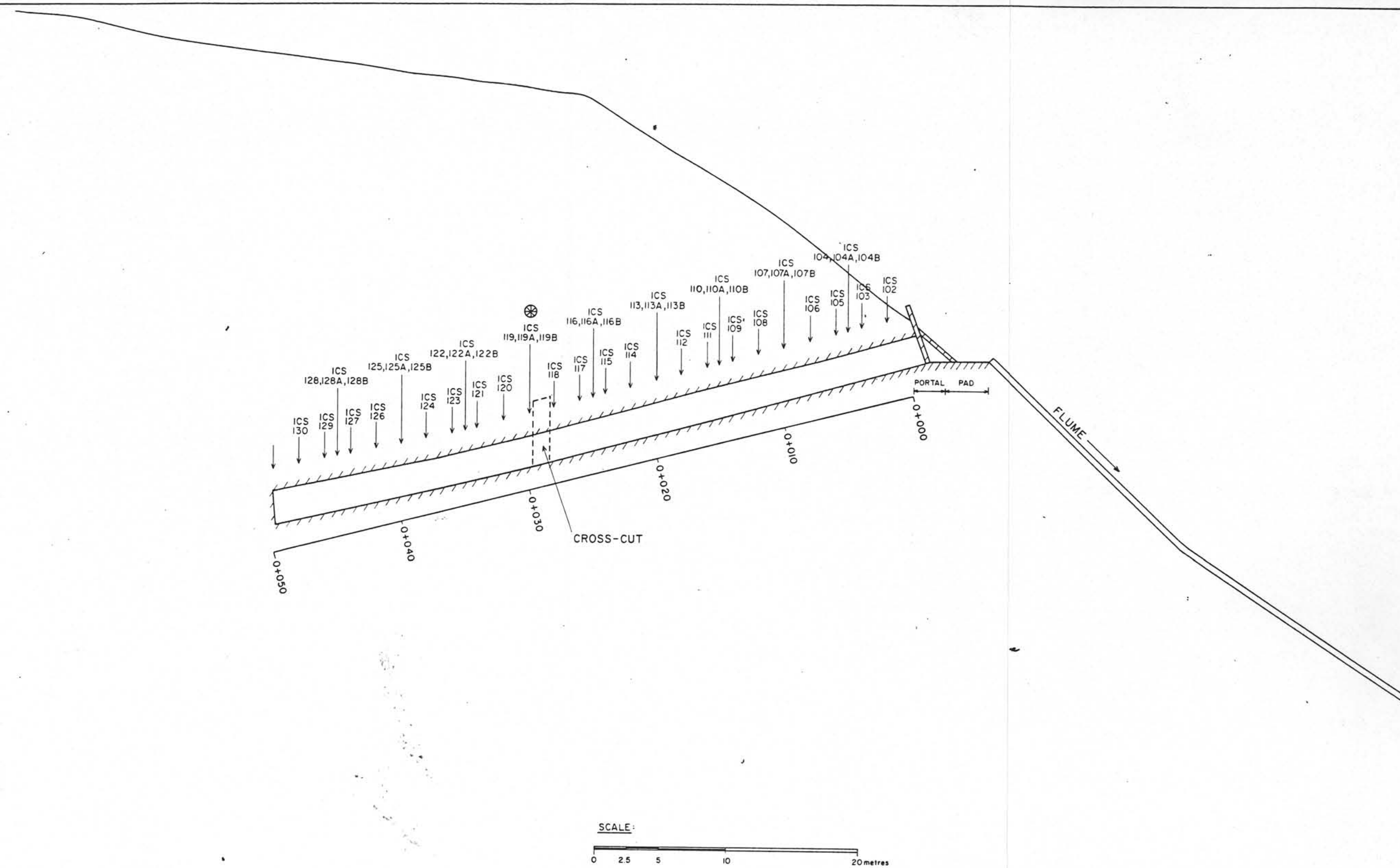
The adit dimensions are approximately 2.0 metres wide by 2.30 metres high. The first 30.0 metres of adit were driven at 14.5° decline, from 30.0 to 36.5 metres at 13.5° and from 36.5 to 50 metres at 12.5° indicating a gradual "shallowing of the slope". The overall decline of the adit is 13°. A cross-cut exposing the full section of the coal seam was driven perpendicular to the adit at 30.0 metres. The cross-cut was taken inclined to the roof of the coal seam at a slope of approximately 18°. A plan and cross-section view of the adit is presented in Figure 4.3 while more detailed diagrams of the cross-cut are found in Section 5.0.

4.5 Incremental Channel Sampling

A series of channel samples were taken at regular intervals from the adit for testing in the field. These samples were crushed, screened and subjected to froth flotation testing in an attempt to establish roughly the level of coal oxidation. The method of analysis and the results are presented in Section 4.6, below, and in Part II of this report, respectively.

The samples taken were hand-picked from the face of the adit as driveage proceeded. Unfortunately, construction at the portal covered the surface coal so that a sample could not be obtained; otherwise the samples were taken at 2 metre intervals. Additional samples were taken every 5 metres from the face and from above the adit roof. These latter samples were obtained by drilling into the roof of the adit with a 1.5 metre auger and taking samples at 0.75 metre intervals. The location of these samples and the method of sample collection are illustrated in Figures 4.4 and 4.5, respectively.

The samples are generally considered to be stratigraphically equivalent, although a thin rock band in the roof of the adit may be partially included in some of the "hand-picked" samples and not in others. Similar samples were collected from the cross-cut before and after bulk sampling. Here, the seam was divided into three zones where the lower-most zone was stratigraphically equivalent to the incremental samples taken by hand pick.



LEGEND

ICS — INCREMENTAL CHANNEL SAMPLE

105 — SAMPLE NUMBER

107A/B — SAMPLES TAKEN BY DRILLING INTO ROOF

⊛ — SITE OF 4-BARREL CHANNEL SAMPLE

GULF CANADA RESOURCES INC. Coal Division CALGARY ALBERTA	Gulf
LOCATION OF INCREMENTAL CHANNEL SAMPLES FOR FROTH FLOATATION TESTING	
FIG. 4.4	
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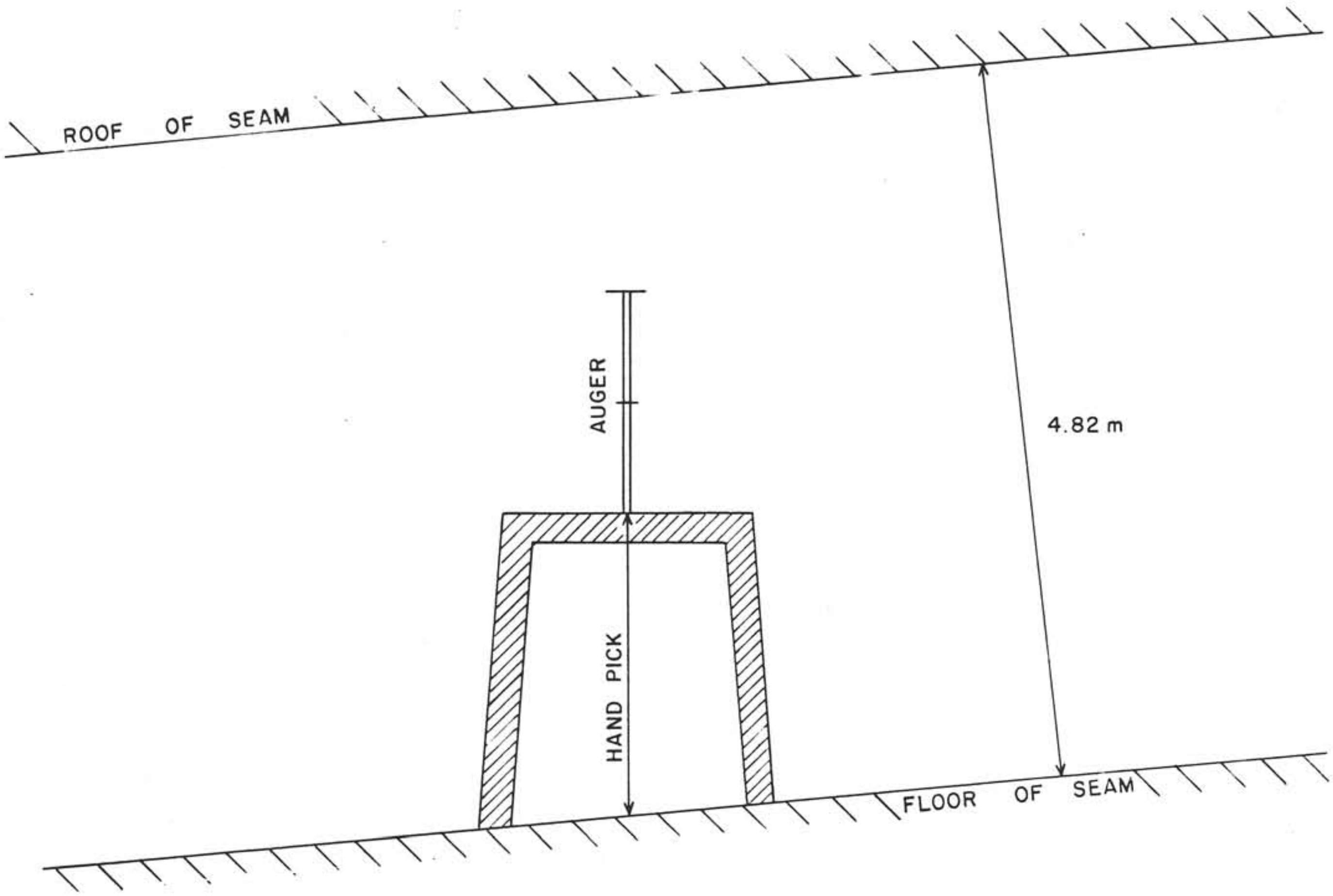
APPROVED BY: JOHN PERRY DATE: DEC.5-83	DRAWING No.



NOTE: Sample obtained by HAND PICK from the adit face every 2metres and 5metres.
Sample obtained by AUGER from roof of adit every 5metres.

SCALE
0 1metres

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Coal Division
CALGARY ALBERTA

SCHEMATIC DIAGRAM ILLUSTRATING METHOD OF INCREMENTAL CHANNEL SAMPLING

FIG. 4.5

PREPARED BY:	SCALE 1:50
APPROVED BY: JOHN PERRY DATE: DEC. 5-83	DRAWING No.

The results of froth flotation tests were somewhate variable and suggest that a number of factors other than oxidation may contribute to the percentage of froth yield obtained. The samples were analyzed further (proximate, sulphur, B.T.U. and Hardgrove Index) by Cyclone Engineering Sales Ltd. to provide some other parameters for comparison with the flotation results.

4.6 Field Analysis

The two facets of the field analysis program were designed to monitor the quality and oxidation level of the coal penetrated by the adit, as the adit was being driven.

4.6.1 Froth Flotation

A froth flotation test was conducted on site by J. Innis using a simplified technique and equipment purchased by Gulf or borrowed from Birtley Coal and Minerals Testing Ltd. Continuous processing of samples as they were received from the adit allowed constant review of the certain coal characteristics. A direct measure of oxidation level was not afforded by the froth flotation results but several observations were made. Part II - Section 3.0 covers this study in detail.

4.6.2 Petrography

Two samples, from the wall of adit driveage, and from an auger penetration of the adit roof were sent to D.E. Pearson and Assoc. Ltd. for vitrinite reflectance determination and vitrinite staining for oxidation testing. This exercise was to serve as a supplementary indication of oxidation levels at different depths of penetration and different seam horizons. A detailed discussion of the procedure and results are presented in Part II - Section 3.0

4.7 Adit Survey

All surveying at the adit site and inside the adit was conducted by Mr. J. Perry using chain and compass techniques.

The location of the portal entrance was established by surveying from drill hole DDH-83001, while the elevation of the portal floor was obtained from many altimeter observations. The co-ordinates and elevation of the portal entrance are:

UTM	Northing 6344350	Easting 505855
	Latitude 57° 14' North	Longitude 128° 54' West
	Elevation	1820 m

Prior to the commencement of bulk sampling the topographic profile from the mouth of the flume to the top of Lost Ridge was surveyed along the direction of the adit drivage. This enabled an accurate calculation to be made of the depth of cover from the ground surface to the proposed sample point.

Upon completion of the work the adit, cross-cut and sampled area were surveyed with respect to headings, slope and dimensions.

5.0 Channel and Bulk Sampling

5.1 Introduction

A series of channel samples and one bulk sample totalling 39.24 tonnes of coal were taken from Seam I. These samples consisted of:

4 - Barrel Channel: - a 0.787 tonne sample taken from the face of the adit at 30 metres.

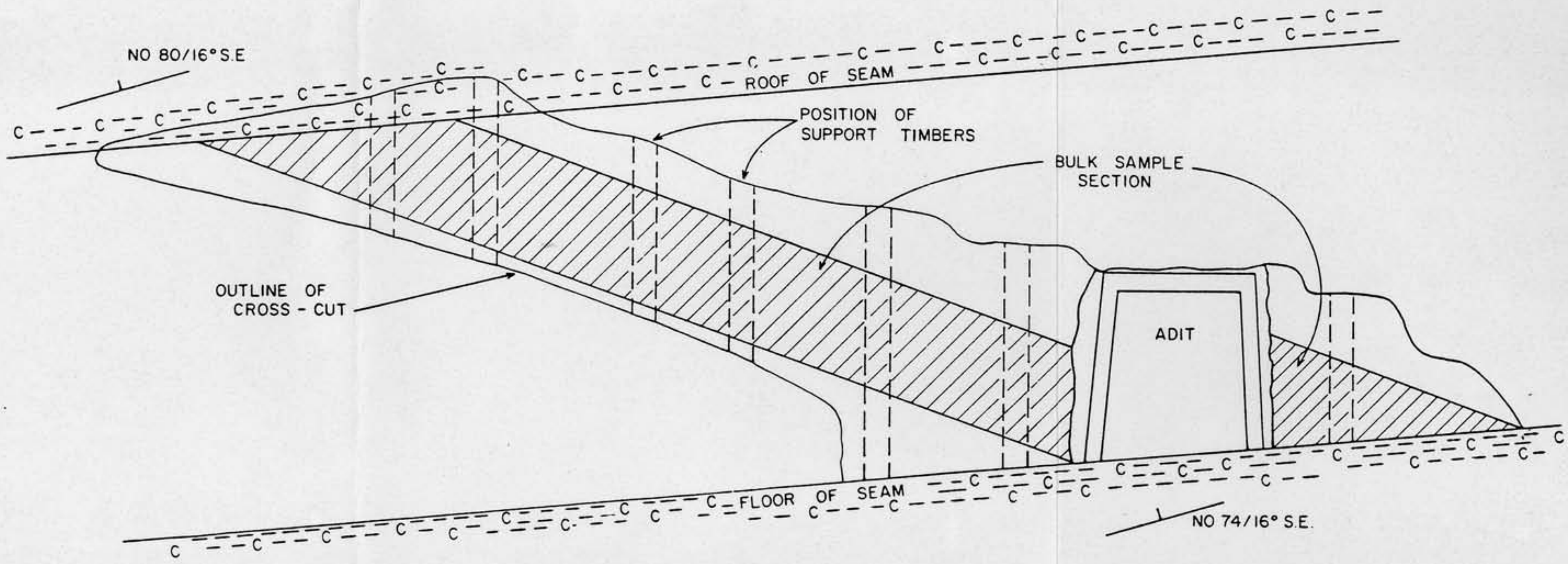
Total Seam Channel: - comprising three separate plys which cover the full thickness of Seam I
Ply 1 - 0.401 tonnes, top portion of seam
Ply 2 - 0.365 tonnes, middle portion of seam
Ply 3 - 0.497 tonnes, bottom portion of seam

Bulk Sample: - 37.191 tonnes, representative of the entire se seam.

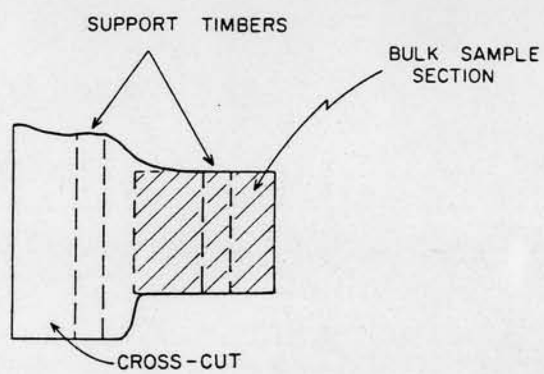
The depth of cover to the roof and floor of Seam I at the 30 metre point was 23 metres and 28 metres, respectively.

The 4 barrel channel sample was taken from the adit face during driveage while the other channel samples and the bulk sample were obtained from a cross-cut. The cross-cut and the location of the various samples are illustrated in Figures 5.1 and 5.2.

CROSS-SECTION ALONG CROSS-CUT



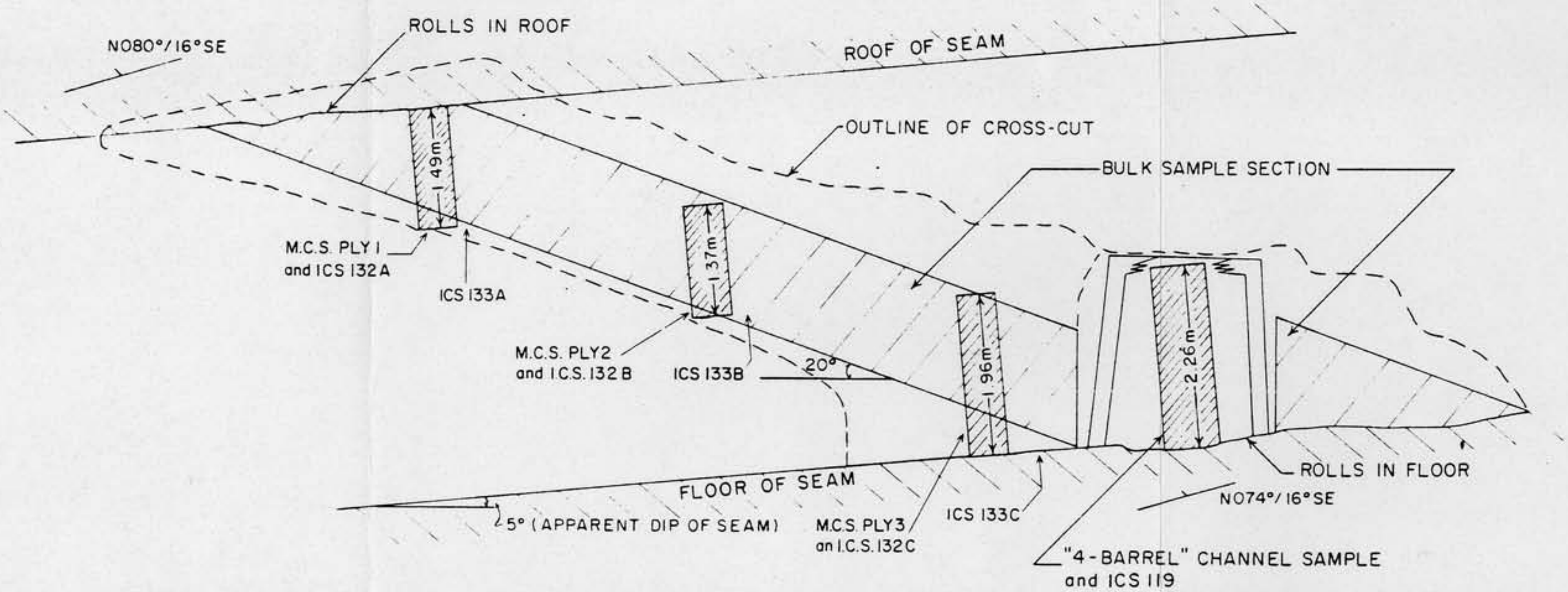
VIEWED TO LEFT HAND SIDE OF ADIT ALONG THE CROSS-CUT AT THE LEVEL OF THE THIRD SUPPORT TIMBER



SCALE
0 0.5 1 2 metres

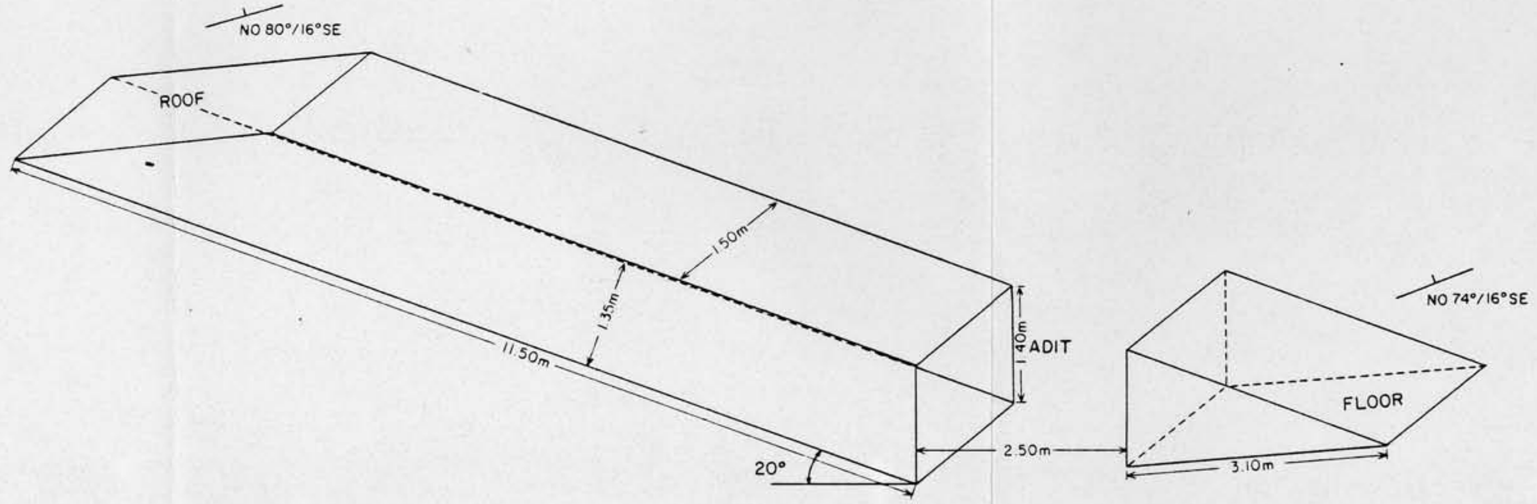
GULF CANADA RESOURCES INC. Coal Division — CALGARY ALBERTA	
DIAGRAM OF CROSS-CUT FOR BULK SAMPLE	FIG. 5.1
PREPARED BY:	SCALE 1:50
APPROVED BY: JOHN PERRY DATE: DEC. 5-83	DRAWING No.

CROSS-SECTION ALONG CROSS-CUT SHOWING CHANNEL SAMPLE LOCATIONS



M.C.S – MAJOR CHANNEL SAMPLE
I.C.S – INCREMENTAL CHANNEL SAMPLE

BLOCK DIAGRAM OF BULK SAMPLE



(N.B. ALL MEASUREMENTS ARE APPROXIMATE)

SCALE
0 0.5 1 2 metres

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Coal Division
CALGARY ALBERTA

DIAGRAMS ILLUSTRATING CHANNEL AND BULK SAMPLES

FIG. 5.2

PREPARED BY	SCALE 1:50
APPROVED BY JOHN PERRY DATE DEC.5-83	DRAWING No.

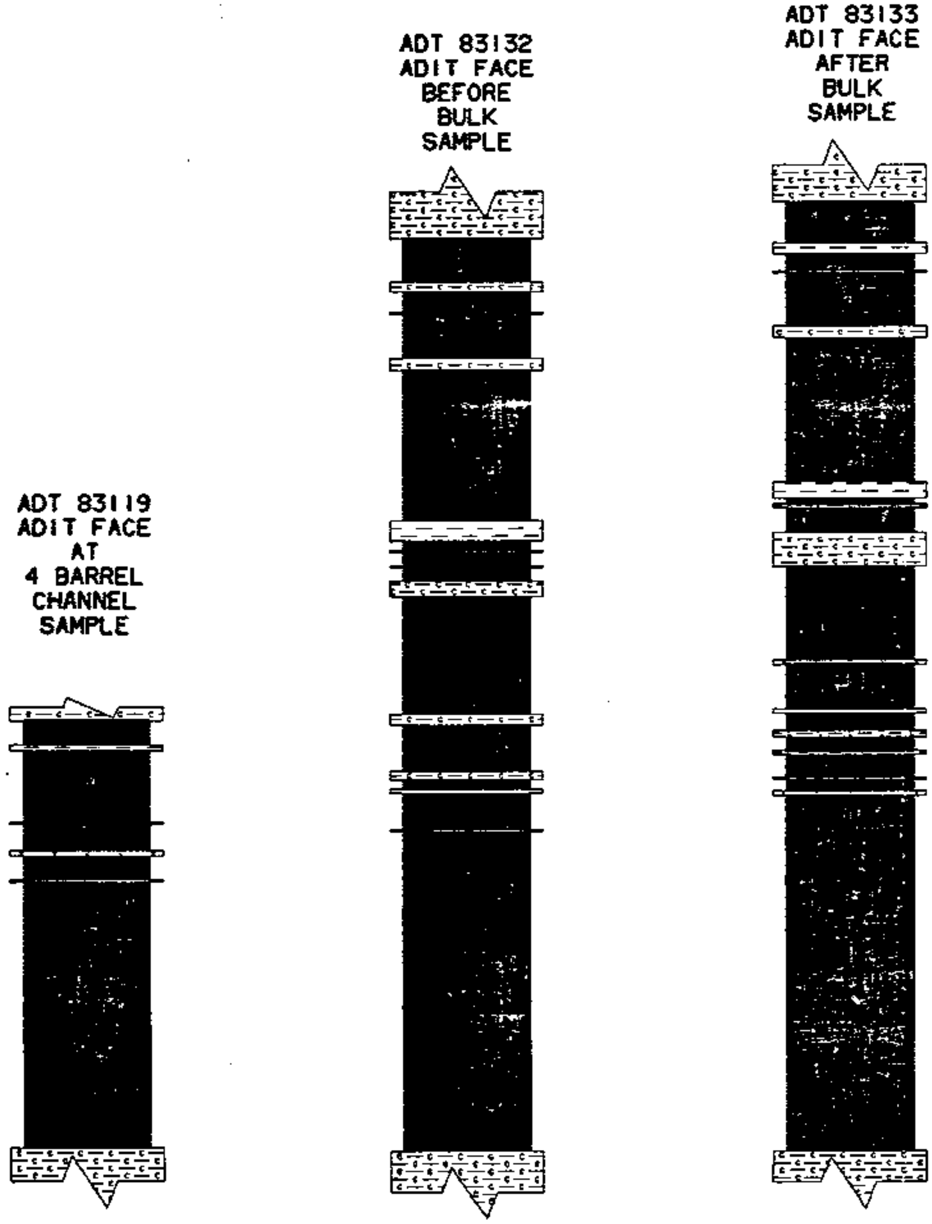
5.2 4 - Barrel Channel Sample

This sample represents only the bottom portion of the coal seam and is equivalent to the incremental channel samples and to Ply 3 of the total seam channel sample. A description of the sampled section is presented in Appendix A and a columnar log of the channel is included in Figure 5.3.

As permafrost was present in the adit at the 30 metre point it was decided that, rather than bulk sample immediately, a small sample should be taken for testing. The purpose of this sample was to determine the size distribution of the coal to see if it was affected by the presence of the permafrost. The sample was taken from a channel of dimensions 2.26 x 0.70 x 0.40 metres (height, width and depth, respectively), loaded into four drums and flown immediately to Calgary.

5.3 Sampling from the Cross-Cut

Deteriorating weather conditions forced a review of the program in late September, 1983. As encouraging results had been obtained from the 4 barrel channel sample it was decided to cross-cut and take the main bulk sample at 30 metres and then, if conditions permitted, take a further sample at 60 metres. The main cross-cut was driven from the seam floor to the roof in the eastern adit wall while a smaller cut was driven in the western wall to compensate for the coal removed in the driveage of the adit, (see Figures 5.1 and 5.2). The cross-cut so produced was used to mine the total seam channel and bulk samples. Driveage of



[205,57]831024101.LOC

GULF CANADA RESOURCES INC.	
MT. KLAPPAN COAL PROPERTY SEAM PROFILES OF SAMPLED SECTIONS FIGURE 5.3	
DRAWN BY:	SCALE: 1:40
APPROVED BY:	DATE: MAR 1984

the adit was stopped at 50 metres and no further samples were taken.

5.3.1 Total Seam Channel Samples

Upon completion of the cross-cut a series of channel samples were taken across the entire thickness of Seam I. Rock bands within the seam divided it into three intervals each of which were sampled separately (see Figures 5.2 and 5.3). The channels were approximately 0.70 metres wide by 0.40 metres deep and 1.49 metres (ply 1 upper), 1.37 metres (ply 2 middle) and 1.96 metres (ply 3 lower) in length. The total sample weight for all the plies was 1.263 tonnes; ply 1 = 0.401 tonnes, ply 2 = 0.365 tonnes and ply 3 = 0.497 tonnes.

5.3.2 Bulk Sample

The bulk sample was taken after collection of the channel samples. It was not considered necessary to take the cross-cut face back to remove the channels as proportional amounts of coal had been remove from each part of the seam. The volume of coal taken from cross-cut was in the shape of a three dimensional parallelogram (Figure 5.2) the dimensions of which were approximately 11.5 metres in length, 1.50 metres in width and 1.35 metres in depth. Special care was taken to ensure that the boundaries of the sample remained parallel so that a fully representative section of the seam was taken.

Most of the sample was mined by blasting. The development of prominent cleats within the coal seam and the presence of some joints in the claystone roof made precise control of the blast very difficult. As a result pieces of coal and/or rock not belonging to the sample had to be identified and removed. Consequently, it was necessary for a geologist to examine the results of the blast before removal of the sample could take place.

As the size distribution of the sample was considered to be of substantial importance none of the pieces of coal or rock were broken down to facilitate handling. All the large peices were loaded by hand into the bucket and barrels and packed around with the smaller pieces. At the end the cross-cut was swept to recover smaller coal particles and dust.

The sample was collected over a period of seven days from October 7, 1983 to October 13, 1983 and arrived at the laboratory in Calgary on October 18, 1983.

Geological descriptions of the cross-cut face before and after bulk sampling are included in Appendix A.

5.4 Geology of the Adit and Sampled Sections

Examination of the excavated coal at the portal showed few effects of weathering beyond the heavy development of permafrost and thin ice veins. The amounts of permafrost and ice decreased rapidly over the first few metres of driveage. The rate of decrease then dropped to a gradual reduction over the length of the adit. Thin ice veins and permafrost coatings on cleat surfaces were noted in various parts of the coal seam within the cross-cut. Occasional peacock staining was seen at the surface. This staining was not noted past the portal except on some occasions where it was present on pieces of waste coal and, occasionally, on the adit walls. Careful examination of the stained coal pieces indicated that the peacock colouration was the result of scorching from the blast and was not due to oxidation.

Another, more prominent, stain or coating on the coal was orange-rust in colour and was present throughout the length of the adit. This stain/coating did not diminish noticeably with depth and covered well developed cleat surfaces. The scraping of a fingernail along these surface often removed the film of colour. This stain/coating was present throughout the seam but was much more prevalent in the highly coated lower portions (i.e. ply 3).

The adit driveage showed that the seam is both stratigraphically and structurally consistent. Minor structures observed were restricted to shear planes sub-parallel or at a high angle to bedding. One sub-parallel shear zone, with a thickness of 0.30 metres suggested the presence of bedding plane thrusts within the seam. The high angle shears were usually thin and well spaced. Occasionally, however, zones containing many such shears would be intersected by the adit; any displacements along these shears would usually be limited to just a few centimetres.

Detailed logging of the cross-cut before and after bulk sampling (Appendix A) gave total thicknesses for Seam I of 4.82 and 5.01 metres respectively. Most of this difference is accounted for in ply 3 and is due to the presence of small low amplitude rolls in the floor. Indeed, there is a difference in thickness of 0.33 metres for ply 3 before bulk sampling and the equivalent section from the 4 barrel channel sample (see Figure 5.3). Similar rolls were found in the roof. Consequently, any seam thickness measurement could differ from another by several tens of centimetres depending upon the points of measurement, relative to the rolls in the roof and floor.

From Figure 5.3 it can be seen that Seam I may be divided into three distinct intervals based on the presence and frequency of contained rock bands. Each interval is roughly equivalent to one third of the seam and is equivalent to plys 1, 2 and 3 of the total seam channel sample. The upper interval (ply 1) contains two main rock bands in its top half ranging from 0.05 to 0.07 metres in thickness. The rest of the ply is essentially rock free. The middle interval (ply 2) contains two main rock bands near the top and many thin bands in the lower half. The upper rock bands vary from 0.08 to 0.18 metres thick while the lower bands range from 0.02 to 0.06 metres in thickness. The lower interval of the seam (ply 3) is essentially free of rock bands except for a couple of thin (0.01 - 0.03 metre) bands near the top.

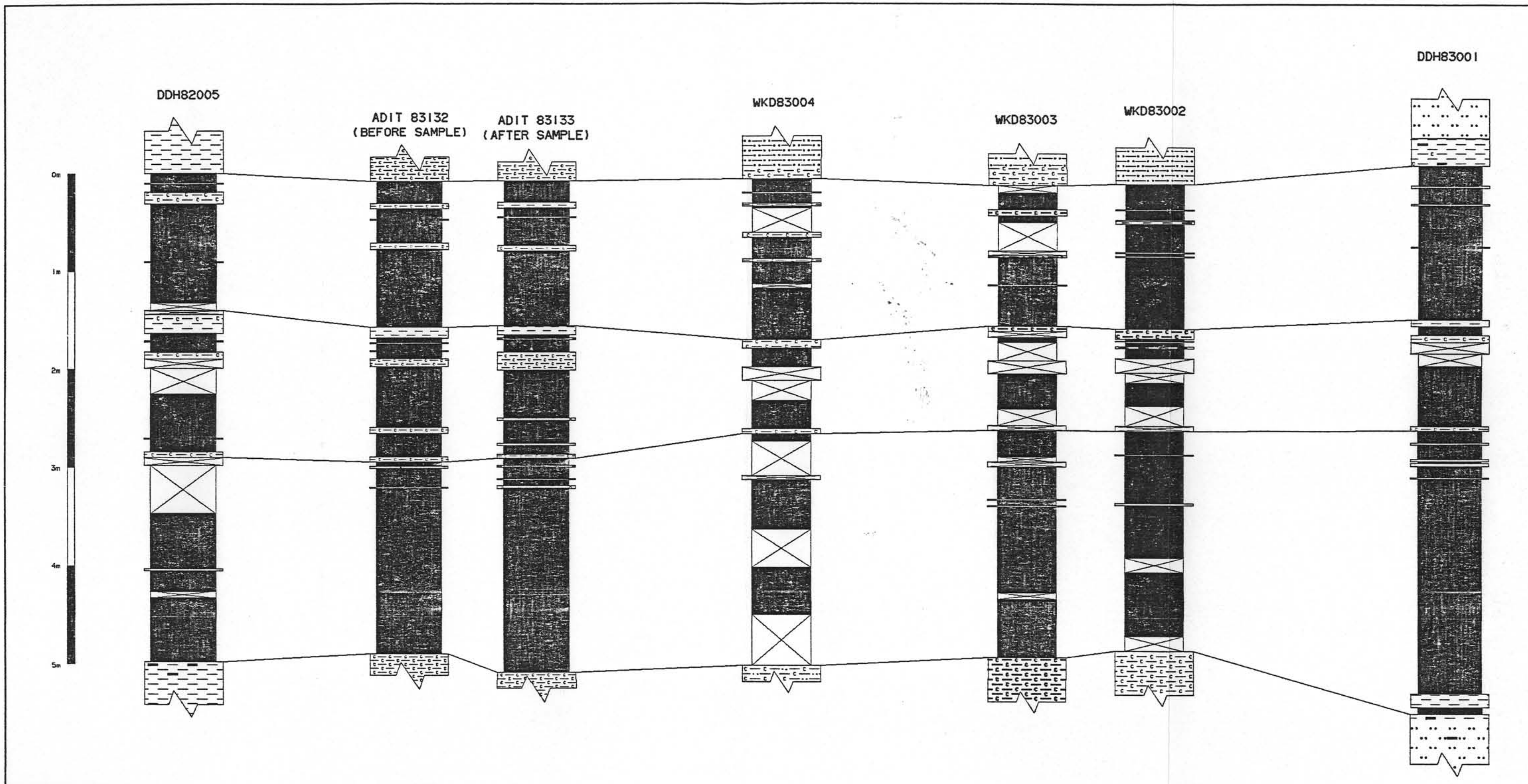
The coal throughout the seam is predominantly bright (80-100% vitrain), hard, with only a few thin bands containing less vitrain and occasional thin boney or stony layers. The coal is often well cleated, particularly in ply 3. Some sheared zones are present as well as some thin crushed zones. These crushed zones are usually cemented by permafrost and as a result are very hard.

Rock bands within Seam I are commonly carbonaceous claystone; the degree of carbon content varies but most bands are highly carbonaceous. Most of the rock bands are poorly bedded, relatively soft and contain thin stringers or rootlets of bright coal. They thicken and thin (by as much as 0.10 metres) rapidly along strike and down dip; some of the thin bands may be discontinuous but the major bands were always traceable accross the length of the cross-cut. Ply 3 occasionally contains some thin (0.01 to 0.03 metre) discontinuous gritty, orange coloured lenses. While most of these can only be traced approximately 0.20 metres they are always found in the same horizons along the cross-cut.

Most of the variations in rock band thickness are considered to be due to sedimentological causes. However, the presence of listric surfaces along the coal/rock contact and within some of the bands does suggest that structural thickening may have contributed to some of the variations. Apart from bedding plane and high angle shears, very little structural disturbance of the seam was noted. Two well developed cleat patterns were present in the coal; the strike and dip of the primary cleat was 170°/84°W and that of the secondary cleat was 094°/77°N. The strike and dip of the roof and floor was quite variable due to the presence of of the rolls. On average however the strike and dip for the roof and floor were 080°/16°S and 074°/16°S, respectively.

The roof and floor of seam were formed by carbonaceous claystone. The contacts for each were quite abrupt; the claystone nearest the coal was highly carbonaceous for the first 0.15 metres or so but then became rapidly less carbonaceous. Both the roof and floor were poorly bedded and quite competent. The roof was not heavily jointed and only slabbed in close proximity to blast points.

A correlation of the adit sections of Seam I with the Winkie and diamond drill holes on Lost Ridge is presented in Figure 5.4. This diagram illustrates the consistent stratigraphic development of the seam accross Lost Ridge. Details of the Winkie core descriptions can be found in Appendix III.



[205,57]831024099.LOC

GULF CANADA RESOURCES INC.	
MT. KLAPPAN COAL PROPERTY CORRELATION CHART INCLUDING ADIT INTERSECTIONS FIGURE 5.4	
DRAWN BY:	SCALE: 1:40
APPROVED BY:	DATE: MAR 1984

6.0 Adit Closure

Upon completion of the bulk sample the adit was sealed in compliance with government regulations.

Support timbers were installed along the cross-cut and sampled section to prevent collapse of the roof and, hence, ensure that the adit can be re-opened at a later date with minimum difficulty.

A large steel door was installed some 5 metres inside the entrance to the adit and padlocked, to seal off access to the tunnel. This door consists of a heavy steel frame and steel mesh which allows circulation of air and any possible gas, and is approved by the British Columbia Government's Mines Inspection Branch. A berm was built across the bottom of the door to prevent any surface water or melt water from reaching the face. In addition any ice or snow build up will be in front of the door which should make for easier access to the adit next spring or summer.

The tugger and bucket were left inside the portal for possible use next year and two magazines, one containing explosives and the other blasting caps, were left on top of Lost Ridge. These magazines are separated by the regulation distance and are securely padlocked. Approximately 30 metres of the bottom end of the flume was removed. However, most of the flume and its wooden supports had to be left in place as they were was solidly iced in.

Demobilization of equipment and camp began on October 16, 1983.

7.0 Reclamation

The full bulk sampling program which included Winkie drilling and adit construction was undertaken on a minimum disturbance basis. All aspects of the work were supported by helicopter and no earth moving equipment was involved in drill site or adit site construction.

No reclamation has yet been carried out.

It is unlikely that any reclamation will be needed on the Winkie drill sites on Lost Ridge as no site preparation was needed. All equipment and garbage has been removed from the sites and if the hole locations were not marked they would be almost impossible to locate.

Due to heavy snow and, consequently, difficult work conditions, no reclamation was carried out on the adit and waste-coal disposal site. Reclamation of these areas will be undertaken in 1984 subject to the necessity of keeping the adit open. As the footpath and adit site were prepared by hand a minimum amount of surface disturbance was caused. Most of the reclamation effort will be concentrated on removing coal from the slope below the adit where it spilled out of the flume, and consolidating the waste-coal below the mouth of the flume and covering it with earth and rock.

All camp equipment has been removed and has been stored either in Smithers or in the B.C.R. trailers at the 1982 camp site. All garbage has been removed and the only remaining items are the wooden tent frames and floors.

MT. KLAPPAN ADIT REPORT PART I

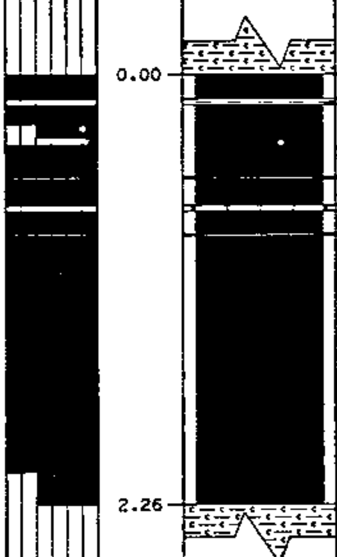
APPENDIX A

DESCRIPTIVE LOGS OF SAMPLED SECTIONS

ADT 83119 = 4 Barrel Channel Sample

ADT 83132 = Adit Face Before Bulk Sample

ADT 83133 - Adit Face After Bulk Sample



SEAM COMP. 1 2 3 4 5 6	DEPTH (m)	COAL SEAM LOG	INTERVAL (m) ROCK	INTERVAL (m) COAL	% REC.	SAMPLE NUMBER	SAMPLE COMPOS.	PROXIMATE ANALYSIS MOIST	ASH	VM	FC	S*	CAL. VAL. MJ/KG	FSI
			TOP OF TUNNEL											
	0.00			0.13										
			0.03											
				0.38										
			0.01											
				0.14										
			0.03											
				0.12										
			0.01											
						06778		3.10	9.20	7.10	80.60	0.54	29.88	
				1.41										
	2.26		0.08	2.18	TOTAL									
			FLOOR OF SEAM											

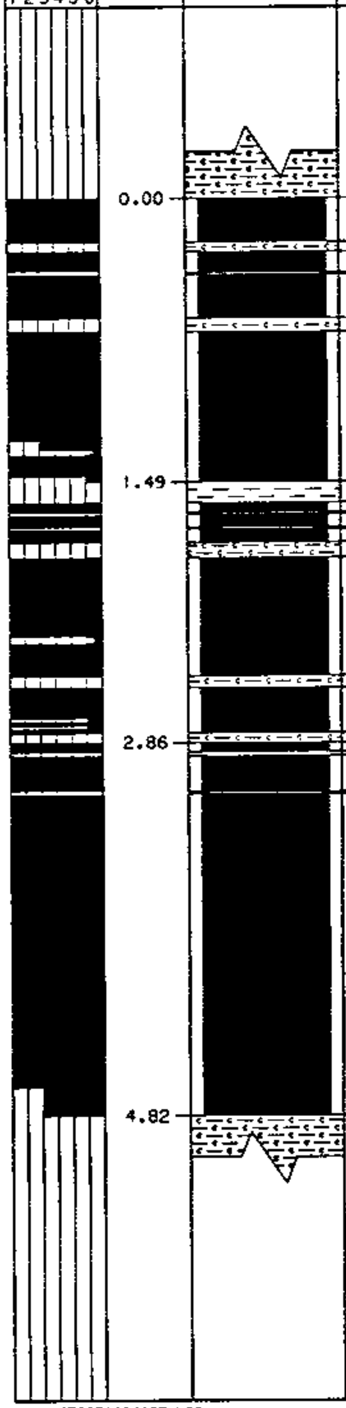
[205,57]831024023.LOG

BOTTOM 2.26m OF SEAM I
(AT +30m)

GULF CANADA RESOURCES INC.

MT. KLAPPAN COAL PROPERTY
SEAM DETAIL
TRUE THICKNESS
ADIT 83119
SEAM I

DRAWN BY:	J. PERRY	SCALE:	1:40
APPROVED BY:	C. WILLIAMS	DATE:	FEB 1984



DEPTH (m)	INTERVAL (m) ROCK	INTERVAL (m) COAL	% REC.	SAMPLE NUMBER	SAMPLE COMPOS.	MOIST	ASH	VM	FC	S'	CAL. VAL. MJ/KG	FSI
	ROOF OF SEAM											
0.00		0.23		06772		2.77	21.37	5.60	70.26	0.43	26.46	
	0.05											
		0.11										
	0.01											
		0.23										
	0.07											
		0.79										
1.49	0.11			06773		2.67	24.93	7.14	65.26	0.38	24.65	
		0.05										
	0.01											
		0.07										
	0.01											
		0.07										
	0.08											
		0.62										
	0.06											
		0.24										
	0.05											
2.86		0.05		06774		4.08	11.47	7.41	77.04	0.44	29.13	
	0.02											
		0.19										
	0.01											
		1.69										
4.82	0.48	4.34	TOTAL									
	FLOOR OF SEAM											

[205,57]831024023.LOG

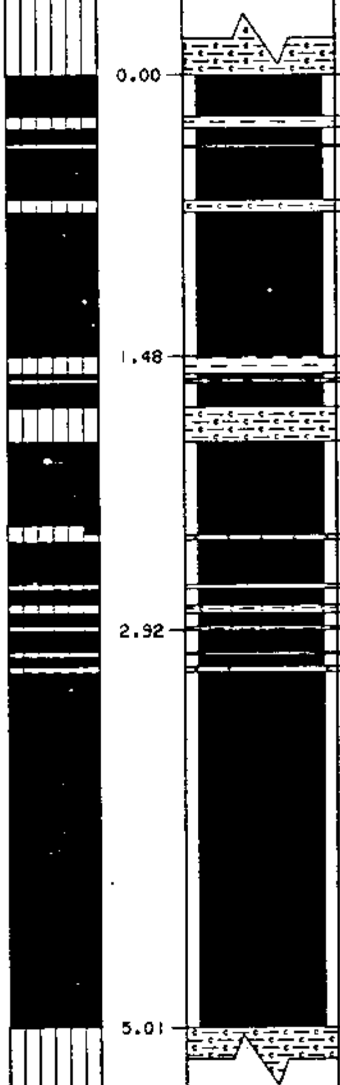
AT CROSS-CUT FACE
PRIOR TO SAMPLING

GULF CANADA RESOURCES INC.

MT. KLAPPAN COAL PROPERTY

SEAM DETAIL
TRUE THICKNESS
ADIT 83132
SEAM 1

DRAWN BY:	J. PERRY	SCALE:	1:40
APPROVED BY:	C. WILLIAMS	DATE:	FEB 1984



DEPTH (m)	INTERVAL (m) ROCK	INTERVAL (m) COAL	% REC.	SAMPLE NUMBER	SAMPLE COMPOS.	MOIST	ASH	VM	FC	S	CAL. VAL. MJ/KG	FSI
	ROOF OF SEAM											
0.00		0.22		06775								
	0.06	0.09										
	0.01	0.28										
	0.06											
		0.76										
1.48	0.09	0.03		06776								
	0.02	0.13										
	0.18											
		0.49										
	0.03	0.23										
	0.02	0.09										
	0.04	0.07										
2.92	0.02	0.12		06777								
	0.01	0.06										
	0.03											
		1.87										
5.01	0.57	4.44	TOTAL									
	FLOOR OF SEAM											

[205.57]831024023.L00

AT CROSS-CUT FACE
AFTER SAMPLING

GULF CANADA RESOURCES INC.

MT. KLAPPAN COAL PROPERTY
SEAM DETAIL
TRUE THICKNESS
ADIT 83133
SEAM 1

DRAWN BY: J. PERRY | SCALE: 1:40
APPROVED BY: C. WILLIAMS | DATE: FEB 1984

PROJECT: KPN BLOCK: LR DATA SOURCE: ADT83119

BCA	DEPTH FROM	DEPTH TO	INTRVAL THICK.	SAMP. ID	SEAM ID	LITHOLOGY	DESCRIPTION
			0.03		I	CLYST	DK.GY.YTHNB SOFT, POORLY BEDDED, SEVERAL ORANGE STREAKS WITHIN. SLIGHTLY CARB.
			0.04		I	COAL	C-6 INTERBANDS OF DARK GREY CLYST AND HARD, DULL AND BRIGHT COAL. (50:50)
			0.17		I	COAL	C-1 VERY HARD
			0.10		I	COAL	C-1 FRIABLE, CLEATED, SOME RUSTY ORANGE STAINING,FEW CLYST LAMS.
			1.00		I	CLYST	CARB.DK.GY ROOF: AT THE BASE OF A CLYST PARTING IN MID-SEAM THAT MARKED THE ROOF OF THE ADIT TUNNEL. CLYST SOFT, POORLY BEDDED AND SHEARED
			0.13		I	COAL	C-1 WELL CLEATED, FRIABLE, SMALL AMOUNT OF PERMAFROST. SOME RUSTY ORANGE STAINING ON CLEAT SURFACES
			0.07		I	COAL	C-3 HARD

* DENOTES MEASURED BCA

PROJECT: KPN BLOCK: LR DATA SOURCE: ADT83119

BCA	DEPTH FROM	DEPTH TO	INTRVAL THICK.	SAMP. ID	SEAM ID	LITHOLOGY	DESCRIPTION
			0.01		I	CLYST	DK.GY ORANGE ZONES, SOFT DISCONT. LENSES UP TO 0.01M.
			0.14		I	COAL	C-1
			0.03		I	COAL	C-6 STONY - CLAY AND COAL - LENTICULAR
			0.12		I	COAL	C-1 WELL CLEATED, FRIABLE
			0.01		I	CLYST	CARB.DK.GY COALY - DISCONT. LENSES
			1.24		I	COAL	C-1 WELL CLEATED WITH HARD BRIGHT COAL BANDS .01 TO .05M THICK.
			0.17		I	COAL	C-3 VERY HARD, RUSTY.
			1.00		I	CLYST	CARB.DK.GY.THNB FLOOR: POORLY BEDDED, SHALLOW ROLLS IN FLOOR. PLANT FRAGS. BEDDING 076/17S.

* DENOTES MEASURED BCA
NEWPAGE

84/03/13 GULF CANADA RESOURCES INC. - COAL DIVISION - DESCRIPTIVE LOG PAGE 1

PROJECT: KPN BLOCK: LR DATA SOURCE: ADT83132

BCA	DEPTH FROM	DEPTH TO	INTRVAL THICK.	SAMP. ID	SEAM ID	LITHOLOGY	DESCRIPTION
	0.00	1.00	1.00		I	CLYST	CARB.DK.GY.THNB.RTB ROOF - SHARP CONTACT WITH COAL, LOW AMP LI. ROLLS STRIKE VARIES FROM 068 TO 080 AND DIPS 13 TO 20 S ROOF COMPETENT THO UGH SOME SLABS DISLODGED BY BLASTING AT T. 080/16S
	1.00	1.23	0.23	06772	I	COAL	C-1 HARD, WELL CLEATED, OCCASIONAL VERT. IC E VEINS AT TOP. MAJOR CLEAT 170/82W, 2N DARY 094/72W
	1.23	1.28	0.05	06772	I	CLYST	CARB.M-DK.GY.VTHNB SOFT,POORLY BEDDED. THICK. VARIES FROM .03 TO .06 M OVER 2M STRIKE LENGTH. OCC . COAL STRINGERS
	1.28	1.39	0.11	06772	I	COAL	C-1 HARD
	1.39	1.40	0.01	06772	I	CLYST	CARB.M-DK.GY.VTHNB
	1.40	1.63	0.23	06772	I	COAL	C-2
	1.63	1.70	0.07	06772	I	CLYST	CARB.M-DK.GY.VTHNB SOFT, POORLY BEDDED - .03 TO .09 M ALON G STRIKE. OCC. COAL STRINGERS

* DENOTES MEASURED BCA

84/03/13 GULF CANADA RESOURCES INC. - COAL DIVISION - DESCRIPTIVE LOG PAGE 2

PROJECT: KPN BLOCK: LR DATA SOURCE: ADT83132

BCA	DEPTH FROM	DEPTH TO	INTRVAL THICK.	SAMP. ID	SEAM ID	LITHOLOGY	DESCRIPTION
	1.70	2.27	0.57	06772	I	COAL	C-1 WELL CLEATED - THIN ICE COATING ON SOME CLEAT SURFACES. THIN DISCONT. CLAY BAN D IN CENTRE. RUSTY ORANGE STAIN ON COAL AT BASE
	2.27	2.32	0.05	06772	I	COAL	C-3 CRUSHED BUT HARD
	2.32	2.35	0.03	06772	I	COAL	C-6
	2.35	2.46	0.11	06772	I	COAL	C-1
	2.46	2.49	0.03	06772	I	COAL	C-6 STONY COAL
	2.49	2.60	0.11	06773	I	CLYST	M-DK.BN.THNB SOFT, POORLY BEDDED, PLANT FRAGS. - .07 TO .12M THICK ALONG STRIKE.
	2.60	2.65	0.05	06773	I	COAL	C-1 SEVERAL THIN CLAY LAMS.
	2.65	2.66	0.01	06773	I	CLYST	M-DK.BN.VTHNB AS CLYST ABOVE

* DENOTES MEASURED BCA

PROJECT: KPN BLOCK: LR DATA SOURCE: ADT83132

BCA	DEPTH FROM	DEPTH TO	INTRVAL THICK.	SAMP. ID	SEAM ID	LITHOLOGY	DESCRIPTION
	4.12	4.13	0.01	06774	I	SLTST	M-DK.GY RUSTY STAINING - IRONSTONE? LENSES UP T O .20 M LONG
	4.13	5.17	1.04	06774	I	COAL	C-1 WELL CLEATED
	5.17	5.47	0.30	06774	I	COAL	C-1 VERY HARD. ICE VEINS IN FACE.
	5.47	5.67	0.20	06774	I	COAL	C-1 WELL CLEATED - RUSTY ORANGE STAINING TH ROUGHOUT FACE
	5.67	5.82	0.15	06774	I	COAL	C-3 HARD
	5.82	6.82	1.00		I	CLYST	CARB.DK.GY.THNB FLOOR: SHARP CONTACT WITH COAL - ROLLS ALSO IN FLOOR. HIGHLY CARBONACEOUS AT C ONTACT. PLANT FRAGS. AND COAL STRINGERS . BEDDING 074/16S

* DENOTES MEASURED BCA
NEWPAGE

84/03/13 GULF CANADA RESOURCES INC. - COAL DIVISION - DESCRIPTIVE LOG PAGE 1

PROJECT: KPN BLOCK: LR DATA SOURCE: ADT83133

BCA	DEPTH FROM	DEPTH TO	INTRVAL THICK.	SAMP. ID	SEAM ID	LITHOLOGY	DESCRIPTION
	0.00	1.00	1.00		I	CLYST	CARB.DK.GY.THNB.RTB ROOF: AS DESCRIBED IN SEAM LOG PRIOR TO SAMPLING. SEE ADT83133.
	1.00	1.22	0.22	06775	I	COAL	C-1 SOME ICE VEINS NEAR TOP
	1.22	1.28	0.06	06775	I	CLYST	DK.GY.THNB SOMEWHAT CARBONACEOUS, SOFT, POORLY BED DED.
	1.28	1.37	0.09	06775	I	COAL	C-1
	1.37	1.38	0.01	06775	I	CLYST	CARB.DK.GY POORLY BEDDED, SOFT
	1.38	1.66	0.28	06775	I	COAL	C-1 SEVERAL THIN (.01M) BONY COAL BANDS
	1.66	1.72	0.06	06775	I	CLYST	CARB.DK.GY SOFT, POORLY BEDDED, COAL STRINGERS AND LAMS.

* DENOTES MEASURED BCA

84/03/13 GULF CANADA RESOURCES INC. - COAL DIVISION - DESCRIPTIVE LOG PAGE 2

PROJECT: KPN BLOCK: LR DATA SOURCE: ADT83133

BCA	DEPTH FROM	DEPTH TO	INTRVAL THICK.	SAMP. ID	SEAM ID	LITHOLOGY	DESCRIPTION
	1.72	2.48	0.76	06775	I	COAL	C-1 THIN (-.01M) CLYST BAND IN CENTRE WHICH REACHES .02 M IN THICKNESS ALONG STRIK E. SEVERAL THIN STONY COAL BANDS NEAR B ASE.
	2.48	2.57	0.09	06776	I	CLYST	M.GY.THNB POORLY BEDDED, SOFT, THICKNESS VARIATIO N ALONG STRIKE.
	2.57	2.60	0.03	06776	I	COAL	C-1
	2.60	2.62	0.02	06776	I	CLYST	CARB.DK.GY.VTHNB SOFT - COAL STRINGERS AND LAMS.
	2.62	2.75	0.13	06776	I	COAL	C-1 OCC. CLAY LAMS.
	2.75	2.93	0.18	06776	I	CLYST	M-DK.GY.THNB POORLY BEDDED, SOFT, CARB ZONES AND SOM E COAL STRINGERS AND LAMS.
	2.93	3.37	0.44	06776	I	COAL	C-1 OCC. CLYST LAMS. AND THIN BANDS
	3.37	3.42	0.05	06776	I	COAL	C-6 BONY

* DENOTES MEASURED BCA

MT. KLAPPAN ADIT REPORT PART II

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MT. KLAPPAN ADIT REPORT PART II

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1.0 INTRODUCTION

A multi-stage program of coal sampling and quality analysis spanned the period prior to, during and following the extraction of the 1983 Mt. Klappan bulk sample.

In Phase I (as described in Part I of this report) a Winkie drilling program provided core samples to verify that coal quality in the target seam was as anticipated from the drilling program of 1982. (See Part II - Section 2.0)

During the driveage of the adit petrography and a field froth flotation procedures was conducted to monitor the oxidation level of the coal (Part II - Section 3.0).

A sample comprising 4 barrels of material was taken mid-way through adit driveage (see Part I - Section 5.2) and analyzed to confirm the expected size analysis (Part II - Section 4.0).

Finally, the bulk sample extracted provided abundant material for a comprehensive product analytical program . Part II - Section 5.0 reports quality results for five products sized between 50mm and 0 on a raw basis and cleaned to 5% and 10% ash.

2.0 DRILLING PROGRAM

The upper and lower intervals of Seam I as intersected by two Winkie drill holes were subjected to complete coal quality analysis to determine if the same coal could be expected in the adit as was sampled in DDH 82-005. Proximate analyses for all Winkie intervals are very comparable to hole -005, though the level of oxygen from ultimate analysis suggests a slight degree of oxidation.

The trend from hole -005 in the east to the Winkie holes in the west is one of slightly decreasing ash in the seam as a whole. The quality of the samples from Winkie drilling verified that there was no substantial change in quality at a distance internally along the seam from hole 005. The point of seam penetration of the deepest Winkie hole (25m depth) was selected as the target point for the adit.

2.1 Introduction

Four Winkie drill holes were spudded along the ridge line of Lost Ridge to obtain core samples of Seam I and to confirm, through quality analysis, the optimum site for adit driveage. Drill holes WKD 83-001, -002 and -003 are all situated about 360m east of DDH 82-005. Drill hole 001 was not completed due to mechanical problems, but drill hole -002, at essentially the same site, penetrated the top of the seam at 12.4m depth and intersected 4.77m of coal with 83% recovery. Hole -003 was 12m south of -002 and penetrated Seam I at 15.5m, intersecting 4.84m of coal with 73% recovery. Drill hole -004 was situated about 280m east of DDH 82-005. It penetrated Seam I at 25.69m and yielded 70% recovery over 4.36m of coal.

Samples from holes -002 and -004 were subjected to complete analysis atBirtley Coal & Minerals Testing. Hole -002 had the best recovery of any hole and hole -004, although it had relatively poor recovery, sampled Seam I in a different area, from beneath a significantly greater amount of cover.

The Seam I intersection from both holes -002 and 004 contained a rock split of .10m thickness about 1.5m from the top of the seam. Hole -004 had an additional 6cm split about 0.5m lower (see Part I, Figure 3.3). In sampling, the core for both holes was split in two, the material from above the rock band comprising one sample, and the material below and including the rock band comprising the second.

Material from each interval was analyzed separately. The reported analyses for the seam as a whole are averages weighted by interval thickness and are not the results of direct analysis (see Table 2.1).

TABLE 2.1

TOTAL SEAM I COMPARISON

	DDH 82-005	WKD 83-004	WKD 83-002
Proximate Analysis			
R. M.	2.5	1.5	1.7
Ash	22.4	24.0	21.2
Vol. M.	7.4	6.9	7.6
F.C.	67.7	67.6	69.5
T.S.	0.4	0.4	0.4
Gross C.V. (cal/g)	6212*	5871	6054
Ultimate Analysis			
Carbon	70.8	68.8	70.7
Hydrogen	2.1	2.2	2.2
Nitrogen	0.8	0.4	0.5
Oxygen	1.0	2.7	3.3
Ash Fusion Temperatures			
Oxidizing Atmos. (°C)			
Init. T	1245	1335	1305
Soft. T.	1300	1390	1390
Hemi. T.	1330	1420	1430
Final T.	1370	1500	1480
Reducing Atmos. (°C)			
Init. T.	1185	1305	1275
Soft. T.	1240	1345	1370
Hemi. T.	1270	1370	1400
Final T.	1315	1445	1460
Ash Composition			
SiO_2	50.5	64.5	62.6
Al_2O_3	24.2	19.9	21.1
Fe_2O_3	8.6	6.6	5.6
CaO	5.0	0.6	1.7
MgO	3.9	2.2	1.8
TiO_2	0.5	1.0	1.0
Na_2O	1.0	1.2	1.4
K_2O	0.9	1.7	1.5
SO_3	3.7	0.3	0.4
P_2O_5	1.2	0.4	1.3

*Calculated

TABLE 2.2

UPPER INTERVAL COMPARISON

	DDH 82-005 Upper	WKD 83-004 Upper	WKD 83-002 Upper
Proximate Analysis			
R. M.	2.5	1.4	1.7
Ash	34.6	15.7	19.1
Vol. M.	7.3	6.3	7.7
F.C.	55.6	76.6	71.5
T.S.	0.3	0.5	0.5
Gross C.V. (cal/g)	5055*	6728	6292
Ultimate Analysis			
Carbon	59.8	76.5	70.5
Hydrogen	1.9	2.4	2.1
Nitrogen	0.7	0.4	0.6
Oxygen	0.2	3.1	5.5
Ash Fusion Temperatures			
Oxidizing Atmos. (°C)			
Init. T	1270	1410	1360
Soft. T.	1385	1440	1390
Hemi. T.	1420	1465	1455
Final T.	1470	1535	1525
Reducing Atmos. (°C)			
Init. T.	1205	1365	1305
Soft. T.	1325	1405	1370
Hemi. T.	1370	1415	1420
Final T.	1430	1520	1500
Ash Composition			
SiO2	58.2	65.4	68.2
Al2O3	26.3	20.5	18.0
Fe2O3	5.3	6.0	4.5
CaO	1.8	0.7	1.3
MgO	2.8	1.4	1.5
TiO2	0.4	0.9	0.7
Na2O	1.4	1.3	1.2
K2O	1.0	1.5	1.4
SO3	1.7	0.1	0.6
P2O5	0.3	0.4	0.4

*Calculated

TABLE 2.3

LOWER INTERVAL COMPARISON

	DDH 82-005 Lower	WKD 83-004 Lower	WKD 83-002 Lower
Proximate Analysis			
R. M.	2.5	1.5	1.7
Ash	14.2	30.0	22.1
Vol. M.	7.5	7.4	7.5
F.C.	75.8	61.1	68.7
T.S.	0.4	0.4	0.4
Gross C.V. (cal/g)	6983*	5257	5957
Ultimate Analysis			
Carbon	78.1	63.3	70.8
Hydrogen	2.3	2.0	2.2
Nitrogen	0.8	0.4	0.5
Oxygen	1.7	2.4	2.3
Ash Fusion Temperatures			
Oxidizing Atmos. (°C)			
Init. T	1225	1280	1280
Soft. T.	1245	1355	1390
Hemi. T.	1270	1385	1420
Final T.	1305	1475	1460
Reducing Atmos. (°C)			
Init. T.	1170	1260	1265
Soft. T.	1185	1300	1370
Hemi. T.	1205	1335	1390
Final T.	1235	1390	1440
Ash Composition			
SiO_2	45.3	63.8	60.3
Al_2O_3	22.8	19.5	22.4
Fe_2O_3	7.2	7.1	6.1
CaO	4.7	0.6	1.8
MgO	0.6	2.7	1.9
TiO_2	0.8	1.0	1.1
Na_2O	0.9	1.1	1.5
K_2O	5.1	1.9	1.6
SO_3	5.1	0.5	0.3
P_2O_5	1.8	0.4	1.6

*Calculated

2.2 Proximate, Total Sulphur & Calorific Value

2.2.1 Upper Interval

Proximate analysis of coal from the upper interval of Seam I in DDH-82-005, WKD-83-004 and WKD-83-002 indicates consistency in moisture and volatile levels, but considerable fluctuation in measured ash levels, and therefore fixed carbon values. Moisture levels are 2.5% (-005), 1.4% (-004) and 1.7% (-002), while volatile levels are 7.3%, 6.3% and 7.7% respectively. The moisture level of -005 may have been affected by a longer delay between drilling and shipping of the sample to the laboratory.

The ash levels of the three intersections are 34.6% (-005), 15.7% (-004) and 19.1% (-002). This is most simply explained via comparison of ratios of recovered coal and rock 1.36/0.55 (coal/rock in -005), 1.22/0.12 (-004) and 1.37/0.06 (-002). Corresponding percentages of recovered rock are 29%, 9%, and 4%. This suggests that the coal itself may be fairly consistent in ash content and changes in ash level in the upper interval are largely a function of the amount of rock included in the seam. There must, however, be a slight shift towards higher ash in the coal between -004 and -002 as the ash level is increasing even though the rock content is decreasing.

Total sulphur values are similar in all three holes. Calorific values are consistent with the trend in ash and range from 5055 cal/g in hole -005 to 6728 cal/g in hole -004.

2.2.2 Lower Interval

Moisture levels in the upper and lower intervals are virtually identical. The sample from DDH-82-005 still shows a somewhat elevated value (2.5%). Volatile contents are also comparable and show great consistency (7.4% - 7.5%). Ash levels in the lower interval are lower for -005 (14.2%) and higher for both -004 (30.0%) and -002 (22.1%). This is not so easily explained by comparing coal rock ratios: 2.00/0.09 coal/rock, 4% rock for -005; 1.55/0.15, 9% rock for -004; 2.43/0.16, 6% rock for -002. The -005 intersection has much less rock in the lower interval, and a corresponding much lower ash level. The -002 intersection shows a slight increase in both rock proportion and measured ash. Intersection -004, however, has exactly the same percentage of sampled rock in the lower and upper intervals, yet a markedly higher ash content in the lower interval.

Total sulphur values are constant for all three samples at 0.4%. Calorific values reflect the ash levels in the lower interval and range from 6983 cal/g. (-005) to 5257 cal/g. (-004).

2.2.3 Total Seam

When the trends in the lower and upper intervals are averaged over the whole seam, the parameters of proximate analyses are quite consistent from hole to hole. Moisture levels still appear to be lower in the Winkie holes than in hole -005 (-002 is 1.7%, -004 is 1.5% and -005 is 2.5%), butash content remains constant at 22-24%, volatiles remain around 7% and fixed carbon levels range from 67% to 69%.

Total sulphur for all samples is 0.4% and gross calorific value ranges just above and below 6000 cal/g (6212 for -005 and 5871 for -004).

2.3 Ultimate Analysis

2.3.1 Upper Interval

Ultimate analysis results for all three samples are quite comparable except for the depressed carbon content of -005, due to the elevated ash level. In addition, the oxygen levels for the WKD samples (3.1% for -004 and 5.5% for -002) seem to be higher than would be expected and are likely affected by a small degree of weathering. Hydrogen levels are relatively constant, ranging between 1.9% and 2.4%. Nitrogen levels range from 0.4% (-004) through 0.6% (-002) to 0.7% (-005).

2.3.2 Lower Interval

The oxygen levels indicate a lesser degree of weathering in the lower intervals of intersections -004 and -002. However, a slightly higher oxygen content in the stratigraphically lower interval of -005 compared with its upper interval reflects the fact that in DDH-82-005 the seam is overturned.

Hydrogen levels are quite consistent for all intersections (ranging from 2.0% to 2.3%). Nitrogen levels exhibit almost the identical trend observed in the upper interval samples, 0.4% (-004) to 0.5% (-002) to 0.8% (-005).

2.3.3 Total Seam

By averaging the interval results together the variations are reduced to some extent. For all samples the carbon level is very close to 70% and the hydrogen level is just over 2%. Nitrogen levels vary in the same way as for each of the intervals separately, and the oxygen levels appear to rise towards the west (1.0% to 2.7% to 3.3% from -005 to -004 to -002) indicating slightly increasing degrees of weathering as the amount of cover declines.

2.4 Ash Fusion Temperatures

2.4.1 Upper Interval

In both oxidizing and reducing atmospheres the ash fusion temperatures for the -004 interval are highest followed closely by -002. The temperatures for -005 are significantly lower than both. In an oxidizing atmosphere the difference between the initial temperature of -004 and -002 is 50°C and between -004 and -005 is 140°C. The respective differences from the final temperature of -004 are 10°C for -002 and 65°C for -005. Temperatures in a reducing atmosphere show a similar trend.

	DDH 82-005	WKD 83-004	WKD 83-002
Oxidizing (°C)			
Init. T.	1270	1410	1360
Final T.	1470	1535	1525
Reducing (°C)			
Init. T.	1205	1365	1305
Final T.	1430	1520	1500

2.4.2 Lower Interval

The fusion temperatures for the lower intervals of -004 and -002 are essentially the same, within the bounds of analytical error, while the temperatures for -005 are again distinctly lower. The trend of separation appears to be the reverse of the upper interval, being (in an oxidizing atmosphere) 55°C between -005 and the Winkie samples at the initial temperature and 170°C at the final temperature.

	DDH 82-005	WKD 83-004	WKD 83-002
Oxidizing (°C)			
Init. T.	1225	1280	1280
Final T.	1305	1475	1460
Reducing (°C)			
Init. T.	1170	1260	1265
Final T.	1235	1390	1440

2.4.3 Total Seam

When results of the upper and lower intervals are averaged, the fusion temperatures for -004 and -002 are roughly 100 to 150°C higher than for -005.

2.5 Ash Mineral Composition

2.5.1 Upper Interval

The relatively small differences in fluid temperatures for the upper intervals are a function of quite similar ash mineral compositions. The silica content of the samples from -004 and -002 is a few percent higher and the aluminum content a few percent lower than for -005, CaO, MgO, Na_2O and Fe_2O_3 levels are comparable, TiO_2, K_2O and P_2O_5 levels are slightly higher and SO_3 levels are lower (by 1.0% to 1.5%).

2.5.2 Lower Interval

The lower interval WKD samples have comparable ash mineral compositions but are quite different from DDH 82-005. The WKD silica levels are higher by about 15% (60% rather than 45%) and the alumina levels are slightly lower (-005 is 22.8%, -004 is 20.3% and -002 is 18.0%). Otherwise, TiO_2, Na_2O and K_2O levels for the WKD samples are slightly higher, MgO, Fe_2O_3 and P_2O_5 levels are significantly lower and CaO and SO_3 levels are much lower. The low ash fusion temperatures of -005 are accounted for by excess silica (SiO_2:Al_2O_3 ratio greater than 2:1) in the presence of iron, calcium and magnesium oxides. The WKD samples have a much greater amount of excess SiO_2 but lack the Fe_2O_3, CaO and MgO to form low fusion temperature compounds.

2.5.3 Total Seam

The average values listed for ash mineral composition are consistent with the trends indicated by the averaged ash fusion temperatures.

2.6 Petrography

A test of vitrinite weathering was conducted by D.E. Pearson and Assoc. Ltd. using a technique of etching with KOH and staining with Safranin-O organic dye. The number of grains stained in a count of 1000 vitrinite grains was determined. Only 4.3% of the grains showed any signs of staining (only weathered grains will stain) and of these most were stained only about the periphery. On a qualitative basis this coal can be described as sustaining a very low level of oxidation and is effectively unoxidized.

This test was conducted on coal taken from the lower level of -002 as this sample was the only one sufficiently large that some might be spared for petrography. It is expected that coal from -004 will show even fewer signs of oxidation.

2.7 Conclusion

There is no significant difference in coal quality between the initial exploration hole, DDH-82-005 and the Winkie holes put down as verification of seam quality continuity, chiefly WKD 83-002 and -004. The quality for the Winkie samples is even better than that found in hole -005 in some regards. Moisture values and ash values in -002 are slightly lower. The only indications of oxidation are mildly elevated oxygen values in the ultimate results from the Winkie holes and the presence of some oxidized vitrinite grains in the lower part of -002. As WKD 83-004 penetrated seam I at a vertical depth of 25m, yielded samples that indicated coal quality well within acceptable ranges, and penetrated the seam at a point within a reasonable distance (30m) of a potential portal, the base of the hole (at the base of the seam) was designated as the target point for the adit.

3.0 OXIDATION TESTING

3.1 Petrography

Coal samples for petrography were taken on the premise that oxidation to any substantial degree will cause reduction in the apparent mean maximum reflectance of vitrinite. As driveage proceeded, two samples were sent to David E. Pearson and Associates for vitrinite reflectance determination and a specific test for oxidation involving etching with potassium hydroxide (KOH) and staining with satranin-O organic dye. A greenish colouration will be absorbed by oxidized vitrinite grains exposed to this dye.

One of the samples examined (04804) was taken by auger driven into the roof of the adit at 5m of driveage. It represents an interval of roughly 1.0 to 1.5 metres from the roof of the seam, where the effects of oxidation should be most noticeable. The other sample (04805) is part of a channel sample taken down the wall of the adit (from the floor to 2.30 m above the floor) at 10 m of driveage. It represents the character of the coal both at greater penetration beneath cover and at a lower level in the seam.

One thousand grains from each sample were examined for staining. The results of analysis were:

	Depth of Cover	No. of Stained Grains	Ro Max.
04804	7m	0	4.06%
04805	13m	0	4.03%

The staining test obviously indicates that oxidation is limited, within the sensitivity of the test, and the reflectance values correspond very closely with what is expected in an unweathered sample of seam I (DDH82005 produced a value of 3.97% reflectance).

3.2 Froth Flotation

The principle of oxidation level determination by froth flotation is that, all other things being equal, an oxidized sample of a coal will exhibit poorer flotation than an unoxidized sample of the same coal. A series of froth flotation tests was conducted on a somewhat experimental basis in the field as the adit was being driven. The tests gave a very broad indication that oxidation levels decreased very rapidly with penetration but the considerable fluctuation between stations indicated that the technique was subject to a number of influences beyond oxidation.

3.2.1 Technique

Two sets of samples were taken at intervals along the adit, one every 2m and another every 5m. The chief difference between the sets was that the 5m incremental samples include material representing almost the complete thickness of the seam, divided into intervals of 0 to 2.30m, 2.30 to 3.20m and 3.20m to 4.00m from the floor of the adit seam. The 2m incremental samples included material only up to 2.30m (the level of the adit roof). The sampling procedure is described in Part 1 Section 4.5.

The equipment used for froth flotation analysis included:

1 geological hammer and steel pan
1 iron mortar and pestle
12 aluminum pans
4 small paint brushes

1 Coleman oil heater
1 thermometer
envelopes
coffee filters
2 filter masks
1 Philips blender
1 Krups KM50 electric coffee grinder
1 100M x 0 screen
1 Sauter balance
diesel oil
methyl isobutyl carbonol (MIBC)
sample bags

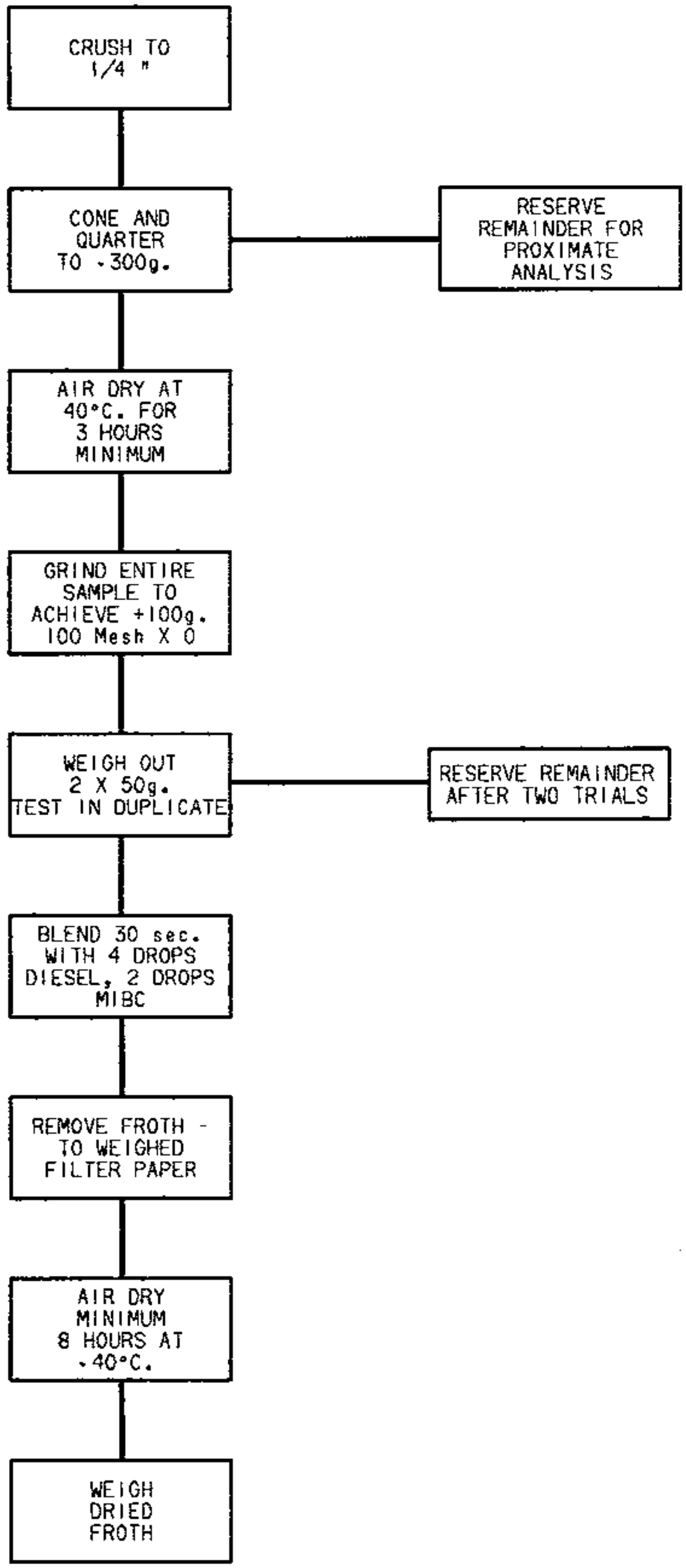
The procedure for analysis is summarized in Figure 3.1. The initial crushing was accomplished by hand and the drying temperature, over the oil heater, was modulated using both the heat control on the heater and the distance of the sample pan above the heater surface. The samples were weighed before and after drying and the moisture loss calculated.

The post drying grinding was a two stage process. The entire sample was crushed once with the mortar and pestle and then run through the coffee grinder as many times as it took to generate 100g of minus 100 mesh material. This varied with the sample and took up to five passes with extremely hard coal.

Frothing would be accomplished as quickly as possible after the sample had been ground to prevent the reabsorption of moisture by the fine material. Two trials of 50g each were run, each time the resulting froth being skimmed off

FIGURE 3.1
MOUNT KLAPPAN 1983

INCREMENTAL ADIT SAMPLES
FROTH FLOTATION ANALYSIS



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onto previously weighed filter paper. The froth was dried on the oil heater for at least eight hours and usually overnight. Drying was judged to be complete by this time, occasional tests with longer drying times yielded no additional weight loss.

After drying, the froth was weighed, the weight of the filter paper (coffee filter) subtracted and all details recorded. The results of the two trials were compared with each other and with results of other samples to detect any experimental irregularities.

3.2.2 Results

3.2.2.1 Lower Seam Interval

As testing for each channel sample station was completed, the results were added to a continuous graph. At the first sample point, 2m into the adit, froth recovery was an average 34.5% between two trials. Two metres further in, at +4m, froth recovery rose to 54.2% of the original sample weight. From here onwards there is fluctuation about this level (average of all channel samples is 49%) but no real trend of increasing recovery beneath greater thicknesses of cover. At +25m froth recovery plunged to 26.6% but was back up to average levels at +26m. Froth recovery also drops into the range of 36-38% at

+5m and +40m but all of these appear to be anomalies in the general trend.

Although the froth analysis program was not a strong indicator of oxidation levels in itself, it did afford an opportunity for close visual inspection of coal sampled at close intervals along the adit. With deeper penetration into the seam an increasing incidence was noted of zones of extremely hard and bright coal. Difficulty was sometimes encountered in the later samples in generating the required 100g of minus 1000 mesh material. Despite this coals very shiny and fresh appearance it sometimes produced lower than average froth recoveries.

3.2.2.2 Upper Seam Interval

The samples taken by auger from the roof of the adit at 5m intervals were used to monitor the oxidation trends in the upper part of the seam. Presumably, the oxidation level might be greater here because the thickness of cover is somewhat reduced. In fact, however, the average froth recovery was marginally higher for the roof samples than for the channel samples from the lower interval, 50.8% for the 2.30m - 3.20m interval and 52.1% over 3.20m to 4.00m from the floor. Again, there is no consistent trend of increasing froth recovery with increasing depth of cover, but the fluctuation between sample stations is less pronounced (see Table 3.1).

3.2.3 Further Analyses

The portion of the incremental samples that remained after the extraction of the subsamples for froth flotation were held in reserve and forwarded to Cyclone Engineering Sales Ltd. for further analyses after the completion of the adit. It was hoped that the measurement of a number of the parameters from these samples would provide sufficient information to shed some light on the fluctuation in froth recovery observed. Proximate, Total Sulphur and Specific Gravity determinations were performed on the 5m incremental samples taken by auger from the roof. These analyses and Hardgrove Grindability testing were performed on the 2m incremental channel samples, and all previous analyses plus Calorific Value were performed on the 5m incremental channel samples.

3.2.3.1 Lower Seam Interval

A possible correspondence was sought between froth recovery and both moisture level, because of its possible effect on surface tension around coal particles, and ash, because of its effect on density. A linear regression was calculated between froth recovery and each of the parameters in turn and a very weak relationship was found with each. There was an unexpected stronger but still insignificant statistical correlation between froth recovery and volatile matter. A moderate relationship was apparent between H.G.I. and froth recovery which bears out the observation made while grinding the samples preparatory to the froth flotation analysis.

Apart from trends in two-variable statistical calculations there is a fairly distinct drop in moisture values from 3.68% at 2m inside the portal to 1.06% at +46m in the adit. Again, there is considerable variation about the general trend, but the trend does exist. There is a corresponding slight rise in calorific value with depth and at lower moisture levels. These latter trends indicate that there is a tendency to lower levels of oxidation at greater depths of cover.

3.2.3.2 Upper Seam Interval

The number of samples available from the upper part of the seam is smaller as the sample points were spaced at a larger interval. Therefore, a statistical correspondence numerically equivalent to one in the lower interval will not be as significant. Several poorly defined relationships exist here as with the channel samples, but there is one quite striking link. A well delineated inversely proportional linear regression appears between ash level and froth recovery. This is the expected trend and may be better defined in the upper interval because ash levels are higher overall (due to a greater number of rock splits - see Part I, Section 5.4) and display a greater range.

4.0 PRELIMINARY SUBSAMPLE

As part of a continuing process of coal quality monitoring, leading up to the extraction of the bulk sample, a preliminary sample was taken at +30m of driveage, comprising 4 barrels (787 kg) of material and representing the total thickness of the seam exposed at the advancing face (see Part I - Section 5.2). The main purpose of the sample was to demonstrate the natural size consisting of extracted coal. With the shearing recognized within the seam (Part I - Section 5.4) it was considered possible that a passive particle size reduction might take place as the permafrost in the coal melted after mining. Alternatively, the action of the frostitself might tend to break down the coal to some degree, the consequences of which could only be appreciated through size analysis after stabilization of an extracted sample at temperatures above freezing.

A further benefit that was derived from the analysis of a preliminary sample was an early look at the proximate parameters and washability by size fraction of at least part of the seam.

4.1 Raw Analyses

4.1.1 Proximate Analysis

A proximate sulphur and calorific value analysis of the entire sampled interval reaffirmed the indications of analyses of previous samples from drill core. The lower part of Seam I is quite low in ash with correspondingly high fixed carbon and calorific values (see Table 4.1). The only unusual value is the slightly elevated moisture level compared with previous measurements (3.10% compared with a maximum of 2.50% in drill core). This situation appears with regularity in the bulk sample as well (see Part II - Section 5.4.1) and is due to an air-drying period inadequate to compensate for the superior moisture retention of the larger particles in bulk samples.

4.1.2 Size Consist

The size distribution of the 4 barrel preliminary sample was measured for the natural coal, and for the naturally larger than 30 mm coal after crushing to pass 30mm. From these screenings the size distribution of run-of-mine coal crushed to less than 30 mm is calculated (see Table 4.2).

The natural sizing of the coal indicates an almost bimodal distribution, with 27% of the the mass existing in particles larger than 30 mm and 36% falling into the less

Table 4.1

PRELIMINARY SUBSAMPLE
RAW COAL QUALITY

RM	3.1%
Ash	9.2%
VM	7.1%
FC	80.6%
S	0.54%
Gross CV	7141 cal/gm

(partially air dried)

Table 4.2

PRELIMINARY SUBSAMPLE
SIZE DISTRIBUTION

(Raw Coal)

	Natural Sizing (i.e. Uncrushed)	+30 mm Crushed	Total Natural Size and Crushed Material
+30 mm	27.1	-	-
30 x 20 mm	12.5%	50.7%	26.2%
20 x 10 mm	13.2%	18.3%	18.2%
10 x 6 mm	11.4%	8.9%	13.8%
6 x 0 mm	35.8%	22.1%	-
6 x 1 mm	-	-	26.1%
1 x 0 mm	-	-	15.7%

than 6 mm fraction. Between 6 and 30 mm the size distribution seems to be very even. A certain brittleness of character is demonstrated by the reaction of +30 mm coal to being crushed to pass 30 mm. Only half of the original material remains above 20 mm in size, almost 1/4 is reduced to less than 6 mm and the remaining 27% falls in between. Despite this material being crushed by hand tamper (the potentially least destructive method for size reduction) the coal appears prone to a significant amount of overbreakage.

4.2 Float-Sink Analyses

4.2.1 Washability

The washability of each of five size fractions was assessed through flotation at 6 specific gravities (see Table 4.3). The washability of all size fractions down to 1 mm are remarkably comparable. There is some variation in the yield of material at 1.50 S.G. but the ash level is consistent at 2.40 - 2.70%. Cumulatively to 1.60 S.G., however, each of these fractions yield between 90 and 95% coal of ash content between 4.70 and 6%. There is a marked increase in ash level in the floats at greater than 1.60 S.G.

The 1 mm x 0 material is the only exception to the general finding. The weight percent is more widely distributed with only a 65% yield at 1.60 S.G. (still with a 4.80% ash level). The increase in ash of elemental fractions above 1.60 S.G. is not as striking but because these fractions make up a greater portion of the whole size fraction the total head ash is higher: 14.50% compared with 8.0 to 8.4% for the other size fractions, bringing the total ash for the entire sample up to 9.2% (see Section 4.1.1 above).

4.2.2 Attrition through Cleaning

A further examination of the degradation characteristics of the coal involved a float-sinking test at a single specific gravity to simulate the effects of cleaning in product preparation. Separate representative samples of each size fraction were floated at 1.6 S.G. Following drying the coal was rescreened and the degradation in each size through cleaning was assessed (see Part II - Table 4.4). In each size approximately 80% of original mass remained in the original size fraction while the remainder fell into finer fractions. There is a strong skew in distribution towards the coarser sizes, suggesting that the degradation in float-sinking is largely due to abrasion rather than fracturing of particles.

5.0 BULK SAMPLE ANALYSIS

5.1 Summary

Analysis of the raw characteristics of coal from seam I was carried out for seven different size fractions between 50mm and 0. The size reduction that occurred during preparation of the sized material from raw as-mined coal points out the necessity for careful planning and efficient handling in order to preserve the coarse fractions desired. Raw coal quality is relatively consistent through all fractions except for a rise in ash level below 1mm.

Product analysis was carried out for each of five size fractions (the three fractions below 1mm examined on a raw basis being combined into one). Yields at 5% and 10% ash improve (from 53% and 80%, respectively, for the 50 x 25mm fraction) toward finer fractions through liberation. Below 1mm yields are lower due to higher initial ash levels. Quality for products is again quite consistent from size to size with most variation being accounted for by differences in ash chemistry and mineralogy.

For all 5% ash products down to 1mm, the gross calorific value is around 7700 cal/gm (a.d.b.). Sulphur levels are uniformly 0.5%, Nitrogen levels are 1.0% or less, and the ash fusion temperatures are consistently high. The quality of 10% ash products in terms of sulphur, nitrogen and ash fusibility is equally high and the calorific value (gross) is 7200-7300 cal/gm (a.d.b.).

5.2 Procedures and Parameters

5.2.1 Objectives

There were three primary objectives of the 1983 Mt. Klappan bulk sample program.

1) To provide information on the natural size distribution of anthracite from seam I in a mining situation.
2) To provide a sufficiently large and representative sample for a comprehensive analysis of a variety of sized coals in raw and cleaned states.
3) To provide material for sample product distribution to a number of interested parties and potential customers.

5.2.2 Methodology

Part I - Section 5.0 describes in detail how the bulk sample was taken. The bulk sample itself was taken to represent the entire thickness of the seam. The sample was to be representative of run-of-mine coal that would be derived from a future mining operation. Other smaller samples were taken by ply to allow comparison with previous ply samples of the seam, and mapping of coal quality variation within the seam.

Care was taken that all parts of the seam were equally represented in the sample and that none of the sample was lost in packing and transportation.

The bulk of cleaning and analysis was done at Birtley Coal and Minerals Testing Ltd. in Calgary. Comparative and specialty analyses were done at Cyclone Engineering Sales Ltd. in Edmonton, Loring Laboratories in Calgary and Coors Spectro-Chemical Laboratories in Golden, Colorado.

5.2.3 Analytical Procedures

The flow sheet (Figure 5.1) illustrates three phases of analysis.

1) Screening and size analysis.
2) Raw coal quality studies and detailed washability analysis.
3) Product preparation and analysis.

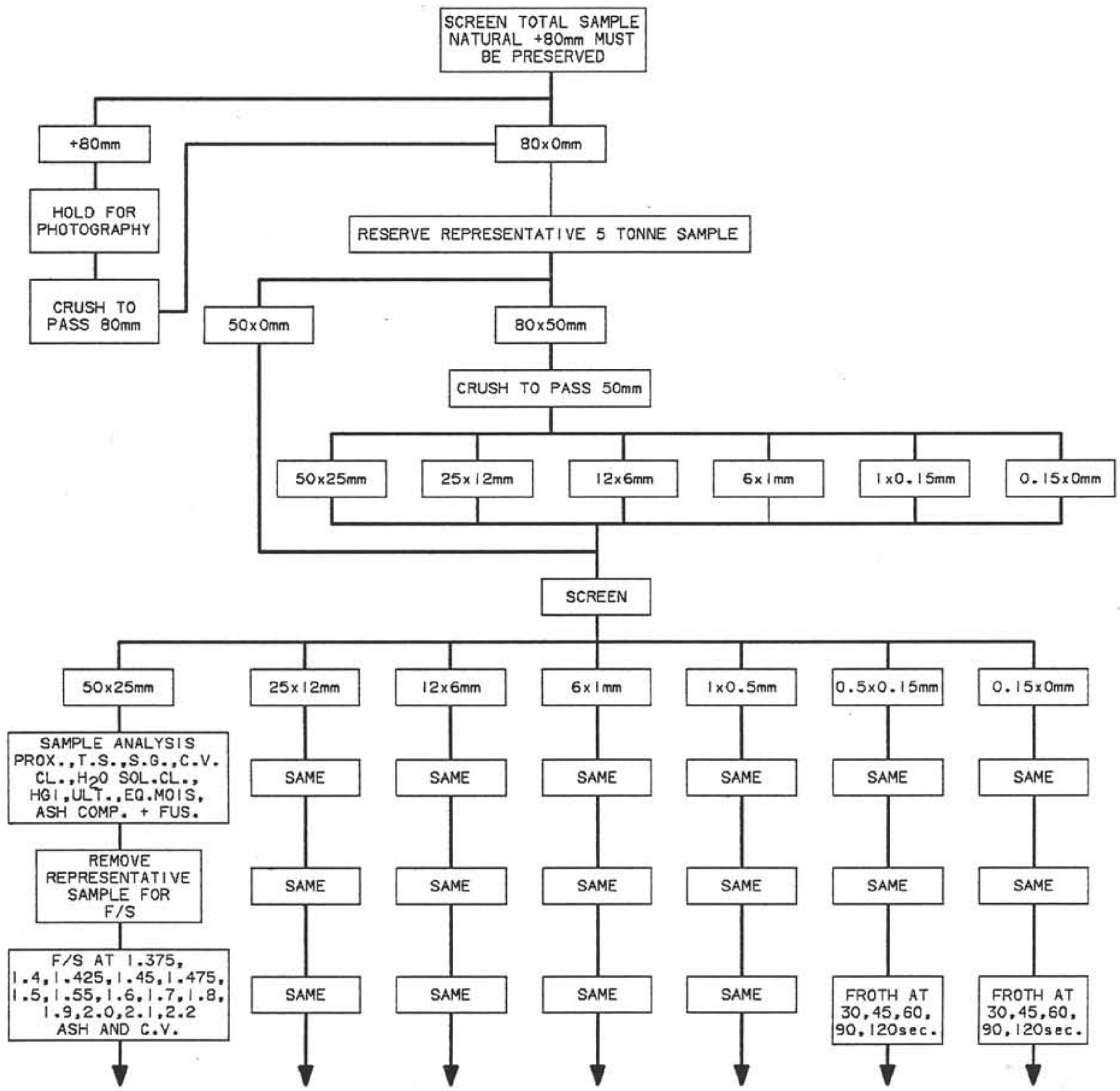
5.2.3.1 Size Analysis

The intensive screening program undertaken with the bulk sample reflects the importance of size consist to anthracite production. Screening was carried out at 80 mm, 50 mm, 25 mm, 12 mm, 6 mm, 1 mm, 0.5 mm, and 0.15 mm. The natural +80 mm material was reduced to less than 80 mm and recombined with the recombined with the sample. Six tonnes of 80 mm x 50

FIGURE 5.1

MT. KLAPPAN COAL PROPERTY

1983 BULK SAMPLE ANALYSIS PROGRAM

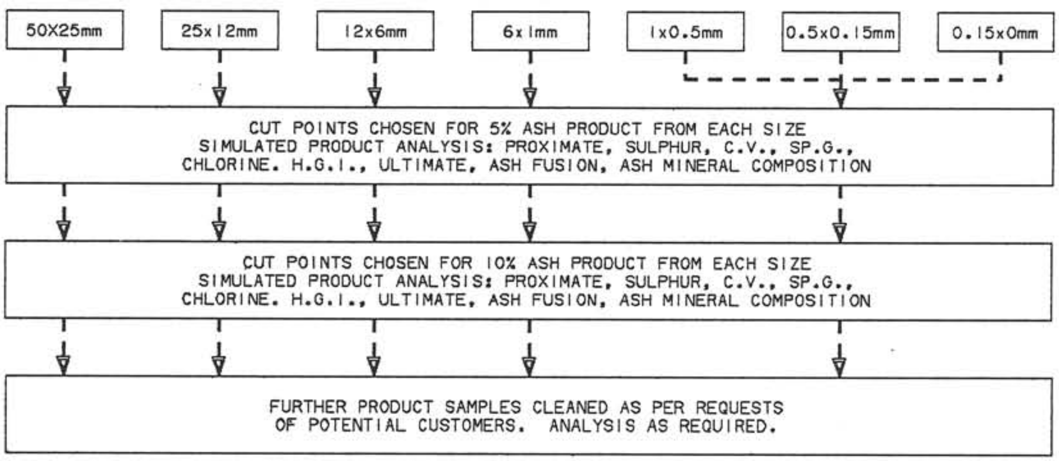


CONTINUED ON FIGURE 5.1A

FIGURE 5.1A

MT. KLAPPAN COAL PROPERTY

1983 BULK SAMPLE ANALYSIS PROGRAM CONTINUED



mm coal was set aside in reserve while the remainder was crushed to pass 50 mm. All analytical and washability studies were carried out on the sized material less than 50 mm. Once segregated by size each fraction was treated as a distinct and separate material. Products were produced from each size fraction individually without combination of more than one fraction. The exception is coal falling into the range below 1 mm. Though raw analyses and float/sinking were conducted for 1 x 0.5 mm, 0.5 x 0.15 mm and 0.15 x 0 fractions, all products were generated from material in the range of 1 mm x 0.

5.2.3.2 Float Sink Data

Material from each of the initial 7 size fractions beneath 50 mm was floated at 14 specific gravities. Between 1.375 S.G. and 1.5 S.G. an increment of 0.025 S.G. was used. Float proportion was also measured at 1.55 S.G. and at 0.10 S.G. intervals from 1.60 S.G. to 2.20 S.G. The concentration on the range below 1.55 S.G. was intended to yield detailed data to assist in the cleaning of low ash products. The two size fractions beneath 0.50 mm were tested using froth flotation at 30, 45 ,60 90 and 120 seconds.

5.2.3.3 Product Analysis

From coal in the size ranges of 50 x 25 mm, 25 x 12 mm, 12 x 6 mm, 6 x 1 mm and 1 mm x 0, products were produced and analyzed at 5% and 10% target ash. Additional analysis was done on miscellaneous products generated at higher and lower ash levels. Analyses included proximate, ultimate, calorific value, specific gravity, chlorine, H.G.I., carbon dioxide, ash fusion temperatures and ash mineral composition. The initial raw analyses included these plus equilibrium moisture and water soluble chlorine.

5.2.4 Terminology

Many of the parameters discussed in comparing and contrasting the coal quality of the size fractions into which the bulk sample was divided show considerable similarity from fraction to fraction. This is to be expected since all the coal of the bulk sample is drawn from a single seam. Some of the trends that do differentiate the coal of one size fraction from the coal of another occur in ash fusion temperatures and ash mineral composition. For the latter, differences are explained not just in terms of the percentage content of various individual constituents, but also in terms of ratios of the content of constituents relative to each other. Many subtleties in the characteristics of an ash are the result of the interaction of several contained minerals.

The ratios used in the discussions of the ash character of raw and product coals are as follows:

$$\text{Silica:Alumina Ratio} = SiO_2\%:Al_2O_3\%$$

A ratio of 2:1 or lower indicates an ash will have a higher fusion temperature than another ash which is similar in composition, but has a silica:alumina ratio above 2:1. Above 3:1 ash fusion temperatures tend to drop off sharply. There is no absolute relationship between this ratio and specific fusion temperatures, other elements affect the range into which the temperatures fall.

$$\text{Silica Percentage} = \frac{100 \times SiO_2}{SiO_2 + Fe_2O_3 + CaO + MgO}$$

This ratio can be applied in similar situations as the silica:alumina ratio. In general, a value of 82 indicates low fusion temperature while 30 or less indicates high fusion temperatures. Other ratios are more strongly linked to ash fusion trends than this one.

$$Fe_2O_3\%:CaO\% + MgO\%$$

Where this ratio is greater than 1 (more iron than calcium plus magnesium), the ash is termed "bituminous type ash". Where the ratio is less than 1, the terminology is "lignitic type ash". This designation can be applied to any coal regardless of its rank. The actual value of the ratio is not important but the balance between these elements can be very influential in determining the degree of significance of other elemental ratios:

$$\text{Dolomite Percentage} = \frac{100 \times (CaO + MgO)}{Fe_2O_3 + CaO + MgO + Na_2O + K_2O}$$

This ratio can be significantly applied only to a "lignitic type ash" that has an acid content (SiO_2% + Al_2O_3% + TiO_2%) less than 60%. These criteria are never met by Mount Klappan coal and the values are quoted for comparative purposes only.

$$\text{Base:Acid Ratio} = \frac{Fe_2O_3 + CaO + MgO + K_2O + Na_2O}{SiO_2 + Al_2O_3 + TiO_2}$$

This ratio has considerable correspondence with ash fusion temperatures throughout all analyses of Mount Klappan coals. For "lignitic type ash", a value less than 0.25 indicates high fusion temperatures while a value over 0.80 indicates low fusion temperatures. For "bituminous type ash", a value less than 0.5 indictes high fusion temperatures and temperatures drop systematically above 0.5.

$$\text{Fouling Factor } (R_f) = \text{Base:Acid} \times Na_2O\%$$

This is not a measure of the fusion behaviour of ash but indicates the potential for accumulation of deposits on the heat exchange surfaces of a furnace through sublimation of gasses produced in combustion. For "bituminous type ash" a figure below 0.2 indicates a low fouling tendency while a figure over 1.0 indicates a severe fouling tendency. This factor cannot be applied to coals with "lignitic type ash" because the high relative content of calcium and magnesium reduces the fouling tendency overall to be out of the effective range of the ratio. A straight reading of fouling tendency can be drawn from Na_2O%. The range (low to severe tendency for "bituminous type ash" is 0.5-2.50%, while for "lignitic type ash" it is 3.0-5.0%.

5.3 Size Consist Analysis

The initial screening, crushing and homogenization of the coal as it was received at Birtley from the adit revealed the same brittle nature as observed in the preliminary subsample (see Part II - Section 4.0). Due to the careful extraction and packing of the bulk sample (Part I - Section 5.3.2) the substantial every coarse size consist of the coal was preserved. Screening at 80 mm yielded 23.6% of the sample coarser then 80 mm with some pieces upwards of 450 mm. Rehandling and crushing the plus 80 mm material to pass through the 80 mm screen resulted in some over-reduction in size. The distribution following the first crushing stage indicated only 5.3% of the sample fell into the 80 x 50 mm fraction while the remainder of the 26% passed not only 80 mm but also 50 mm.

After reservation of 6 tonnes of 80 mm x 0 material, all remaining +50 mm coal was crushed to less than 50 mm. Again, the brittle nature of the coal created a degree of over-reduction and final distribution was slightly skewed towards finer sizes, with the most stable size consist appearing to be 6 x 1 mm (33.6%). The proportion of the total sample in coarse size fractions did not conform to the earliest indications but over 1/3 of the sample remained coarser then 6 mm (see Table 5.4).

5.4 Raw Coal Quality

The entire 31 tonnes of sample remaining after the 80 mm x 0 reserve was screened at 25 mm. The quantity of material below 25 mm was stored as 25 x 0 mm with representative quantities being extracted to provide sized samples for raw and product analyses. The results of raw analysis of seven size fractions between 50 m and 0 are summarized in Tables 5.5 through 5.11.

5.4.1 Proximate, Sulphur, C.V., H.G.I.

The unique quality of the bulk sample analysis program was that each of a number of size fractions was analyzed, float-sinked and cleaned into various products individually. Several trends of variation among certain parameters were noted that had not previously been encountered in analytical programs concentrating exclusively on drill core.

Moisture content of air dried raw coal was found to fluctuate quite substantially depending on size fraction. The coal was dried under controlled conditions for a length of time that experimental experience indicated should conform with A.S.T.M. standards. It was found, however, that the coarser coals (as 50 x 25 mm) and the coals with higher ash content retained far more moisture than was expected from past analysis of drill core samples. Moisture levels were 3.20% for 50 x 25 mm coal and around 5.0% for all fractions less than 6 mm. The size fraction about the same size range as drill core (12 x 6 mm) had about the same moisture level

(1.20%). To combat this problem, samples from each size fraction were reduced (if necessary) to less than 6 mm and then all were dried under more carefully controlled conditions while weight loss was monitored. Most fractions under these circumstances yielded a moisture value between 1 and 1.5%. It is these moisture values that are reported on Tables 5.5 to 5.11.

Ash content is quite consistent in general. The coarse fraction, down to 6 mm, contains about 20% ash with levels gradually declining with size (through liberation effect) to a low of 13.9% in the 6 x 1 mm fraction. Below 6 mm the ash level rapidly rises again to 38.4% in the 0.15 mm x 0 fraction, an effect often observed in drill core (see Mount Klappan reports for 1982 and 1983) and due to the ash material being softer than the coal and falling naturally into the finest size fractions.

Volatile matter content also exhibits a trend not previously observed. Values are quite consistent through most size fractions (on both an air dried and dry mineral matter free basis) but then rise in the finest fractions. Carbonate content is only slightly higher in the fine size fractions and may account for some of the difference. Another effect though is likely, as with moisture, a reflection of increasing ash level. Hydrated clays in the ash contain both physical moisture (raising the apparent moisture level) and chemical moisture, bound into the clay molecules and not released until temperatures employed in volatile content determination are reached. This chemical water vapour, then, will contribute to the volatile content and will cause that content to fluctuate with ash level. It can be seen that the 6 x 1 mm fraction, with the lowest ash content, also has the lowest volatile content. Also, because clay minerals will generally degrade into the finest size fraction, the fine fraction will have higher volatile levels even at constant ash levels (see Part II - Section 5.5).

Fixed carbon levels average about 70% for most size fractions and decrease in the high ash finer fractions. Sulphur levels are quite consistent at around 0.40% through all size fractions. The calorific value varies universely with ash and is also quite strongly influenced by moisture level. This has been observed through comparison of initial calorific values and values measured after repetition of drying. The Hardgrove Grindability Index, as expected, rises in the finer fractions from an initially constant value of 37 through all size fractions above 6 mm.

5.4.2 Ultimate Analysis

Ultimate analysis of each size fraction in raw form indicates that there is substantial variation in ultimate composition from size to size. Apart from the variability in moisture, described above, and that in carbon caused chiefly by fluctuation in ash, hydrogen levels are fairly consistent around 2% and nitrogen and sulphur levels range around 0.4%. Oxygen levels, between 3 and 4%, indicate a slight degree of oxidation as was previously observed (see Part II- Section 2.3).

5.4.3 Ash Fusion and Ash Mineral Analysis

There is consistency also in ash fusion temperatures between size fractions. Temperatures in general are quite high, with the lowest initial deformation temperatures (in a reducing environment) being just over 1200°C. and the highest fluid temperatures (in an oxidizing environment) being just under the maximum reading for the equipment used, at 1530°C. The temperatures at the four points of measurement rise and fall almost in concert, the range from initial deformation to fluid temperatures (in either atmosphere) varying from 170°C to 270°C but generally falling around 220 - 240°C. There is also good correspondence between oxidizing and reducing temperatures, the difference between the two being in most cases less than 50°C.

There is a trend in fusion temperatures noticeable from fraction to fraction in which, from the coarsest size (50 x 25 mm), the fluid (and all) temperatures rise to peak in the 1 x 0.5 mm fraction and then drop off again. The span is from 1425°C to 1530°C. This trend can be directly linked to the ash mineral composition measured in each fraction and may be a function of the habit of mineral matter in the coal, its reaction to progressive liberation and its possible tendency to concentrate in the finer fractions (as part of the ash material) Apart from this mild variance, the ash character of each fraction, as measured by ash fusion temperatures is quite similar.

The chief difference in ash mineral composition of the 1 x 0.50 mm fraction compared with the others is the low silica: alumina ratio; just over 2:1 compared with almost 3:1 in the 50 x 25 mm fraction. Below a ratio of 2:1, fluid temperatures are found to rise quite rapidly as the ratio decreases. Temperatures drop gradually between ratios 2:1 and 3:1 and then more quickly above 3:1. The temperature fluctuation is a function of available excess silica to combine with other oxides (chiefly calcium, magnesium, iron, sodium and potassium) to form compounds with depressed melting temperatures. The silica ratio, which compares silica content with the contents of iron, calcium, and magnesium is another measure of the tendency of ash to melt at lower temperatures. A silica percentage of 82 is considered a benchmark in the scale of fusion temperatures. The ash from the 1 x 0.5 mm fraction is the only ash to have a silica percentage below 82 (81.65); the other fractions have marginally higher percentages (in the range of 85 to 87) and correspondingly lower fusion temperatures.

Several general observations can be made on the ash from all size fractions. Regardless of the rank of a coal, if its ash has an iron content greater than the contents of magnesium and calcium combined, then it can be characterized as a coal with a "bituminous type" ash. Such is the case with the raw coal from seam I. Several indices can be used to assess the slagging and fouling potential of a bituminous coal.

In the case of seam I, some of the indices are found to conflict. The silica percentage indicates a slagging potential at the high end of the range (over 82) while the base to acid ratio (comparing the contents of iron, calcium, magnesium, potassium and sodium with the sum of silica, alumina and titanium contents) points to an extremely low slagging potential. The measured fusion temperature would seem to support the latter indicator.

Similarly, the fouling potential as indicated by sodium alone (1.5 to 1.6%) is again high, but the fouling factor (base:acid ratio/sodium content) is low (0.2 to 0.3). The mineral balance of the ash appears to be generally favorable through all size fractions.

5.4.4 Washability

There is minor variation in the washability characteristics of the coal in different size fractions (see Appendix A). As mentioned previously, the head ash in each size fraction is around 20% down to 0.5 mm (slightly lower in the 6 x 1 mm fraction). Cleaning to 5% ash can be accomplished for each fraction, down to 0.5 mm, at an S.G. of 1.55. There is some fluctuation in ash level ($\pm$0.5%) and the laboratory yield rises from 57% in the 50 x 25 mm fraction to the 6 x 1 mm fraction. There is a slight decrease in yield (58%) in the 1 x 0.5 mm fraction but the ash is also lower (4.50%). This is a function of increasing liberation in the finer sizes. No 5% ash product can be produced from the two froth fractions below 0.5 mm due to their accumulation of the soft and, therefore, generally fine ash material.

Comparison of the cut points for 10% ash from fraction to fraction produces an even more vivid demonstration of the effects of liberation. For the coarsest fractions (above 12 mm), a cut point of 1.80 S.G. will yield 83% of an approximately 10% ash product. Maintaining the same ash level, the cut point climbs to 2.00 S.G. for an 89% yield in the 12 x 6 mm fraction and 2.20 S.G. for a 93% yield in the 6 x 1 mm fraction. The yield at the same cut point (S.G. 2.20) in the 1 x 0.5 mm fraction is down to 89% at a slightly higher ash (10.4%). suggesting that this fraction has inherited some of the ash liberated from the slightly coarser coal that becomes more concentrated in the finer fractions below. The 1 x 0.5 mm fraction appears to be at a node between two trends, the progressive liberation which leads to lower ash and better cleaning at finer sizes, and the progressive accumulation of liberated ash which causes increasing ash levels in the very finest fractions.

Below 0.5 mm froth flotation testing indicates a 32% yield of 10% ash material in the 0.5 mm x 0.15 mm fraction. 10% ash material does not appear in any froth fraction of the 0.15 mm x 0 size coal.

5.5 5% Ash Product Quality

Analyses were conducted for a 5% ash product derived from each size fraction. Below 1 mm the material was combined into a single fraction (1 mm x 0) as there is no demand for low ash products at finely divided fractions in this size range.

5.5.1 Proximate, Sulphur, C.V., H.G.I.

A similar problem with moisture was encountered in the 5% ash product analyses as in the raw analyses. The moisture retention in the coarse fraction was higher than expected and therefore moisture values measured after the application of standard drying techniques were also high. Re-measurement using the same techniques described is Part II - Section 5.4.1 produced moisture values between 1 and 2%. These values are reported on tables 5.12 through 5.16 along with values for proximate, ultimate and calorific value determinations adjusted to compensate for the lower moisture.

Products at 5% ash were obtainable from all size fractions generally at yields between 50% and 67%. The 37.5% yield from the 1 mm x 0 fraction is likely largely drawn from coal above 0.5 mm in size considering the washability of the fines below 0.5 mm (see part II - Section 5.4.4 and Appendix A). The yields reported on the following tables are those achieved in actual bulk float-sinking and may differ slightly from those discussed in Part II - Section 5.4.4).

Volatile matter contents measured from the low ash products are not as affected by interference from ash mineral breakdown and are therefore generally lower than for the corresponding raw analysis. Some interference is seen in the finest fractions (below 6 mm) wherein the ash material that remains is likely to contain a higher proportion of fine clay material. A higher proportion of clay in the same percentage of ash will have a greater effect on measured volatiles.

Fixed carbon levels reflect the cleaning of the coal to a constant 5% ash and most are at about 87%. The fixed carbon value for the 1 mm x 0 fraction is depressed to 84% because of its elevated volatiles. Sulphur values are very consistent at 0.5%. Calorific value largely reflects ash level and ranges around 7700 cal./g. (gross) through all sizes except the 1 mm x 0 fraction. In this fine fraction, despite the moisture and ash levels being consistent with the analyses of other size fractions, the gross calorific value is only 7400 cal./g. This corresponds with the elevated level of volatiles in that the difference in heat value from other fractions is due to increased moisture retention in the clay constituents of the ash. The excess heat generated in other fractions is here absorbed in the process of breaking down hydrated clays. Once the clays are degraded, the released moisture appears as part of the volatile content (see discussion in Part II - Section 5.4.1).

Variation in the Hardgrove Grindability Index between size fractions cleaned to 5% ash and between the product and raw analyses of respective size fractions are largely a function of ash level. The H.G.I. at 5% ash through all fractions down to 1 mm is between 30 and 32, compared with 37 to 40 in raw coal. As the H.G.I. rose in raw coals with ash level (towards the finer size fractions), it also rises slightly (to 40) in the 5% ash products as the ash composition changes. In addition, the inclusion of some fine material (less than 0.5 mm) in the 1 mm x 0 5% ash product may artificially influence the apparent reading of H.G.I.

5.5.2 Ultimate Analysis

Cleaning of the raw coal to 5% ash products alters the balance of ultimate constituents, but, except for the 1 x 0 mm fraction, there is little variation in product analyses from size to size. Carbon levels are uniform at about 86% and nitrogen levels are just under 1%. Oxygen content ranges from 2.6% to 3.9%. It is slightly lower than for the corresponding raw fractions and accompanies the reduction in apparent volatile matter. The ultimate analysis of the 1 x 0 mm 5% ash fraction is comparable in all respects to the coarser fractions except that carbon levels are lower (80.9%) and oxygen levels are much higher (8.2%). The elevation of the oxygen content correlates with the raised volatile matter content and suggests again that the volatiles are not derived so much from the coal as from the ash. A rise in combustible volatiles should be accompanied by a rise particularly in the hydrogen content. That the excess volatiles in the 1 x 0 mm fraction relative to coarser fractions occur with relatively higher oxygen content indicates that the additional volatile matter is largely composed of water vapour, derived in all probability from clays in the ash.

5.5.3 Ash Fusion and Ash Mineral Analysis

The general trend in fusion temperatures observed in the raw analyses is also seen in the 5% ash products, with some variation and at a higher overall temperature. From the coarsest to the finest fractions ash fusion temperatures rise. Trends are noticeable only below the final or fluid temperature. However, because in both oxidizing and reducing temperatures, the fluid temperature in all fractions is in excess of the capacity of the furnace used (over 1540°C). The hemispherical temperatures in both atmospheres rise together from about 1450°C to 1510°C for the 50 x 25 mm and 1 mm x 0 fractions, respectively. The separation between oxidizing and reducing temperatures varies between 10°C and 45°C. Softening temperatures in oxidizing and reducing atmospheres also exhibit comparable trends. In an oxidizing atmosphere the softening temperature rises from 1400°C in the 50 x 25 mm fraction to 1500°C in the 1 mm x 0. Temperatures in a reducing atmosphere are about 75°C to 100°C lower. The most marked difference between oxidizing and reducing atmospheres, and the largest rise in temperature from the coarsest to the finest size fraction is noted in the initial deformation temperatures. In a reducing atmosphere the temperature is almost constant through all fractions, at 1250°C to 1275°C. In an oxidizing environment, however, the initial deformation temperature rises from 1255°C in the 50 x 25 mm to 1435°C in the 1 mm x 0 fraction. Overall, the span between fusion temperatures in oxidizing and reducing atmospheres reduces systematically from the initial to the final measurement point.

There is a significant variation in the ash mineral composition of the different size fractions to account for the above described trends in fusion temperatures. The most apparent variation between size fractions is the increase in silica (SiO_2) content from 41.4% in the 50 x 25 mm fraction to 56.8% in the 6 x 1 mm fraction. This is accompanied by a consistent drop in alumina (Al_2O_3) content from 33.8% to 27.9% between the same two fractions. The most significant general difference between the mineral composition of raw ash and the composition of the ash remaining after cleaning to a 5% ash product is the alteration of the balance between iron and the sum of calcium and magnesium oxides. While the ash in raw coal of all size fractions is characterized as "bituminous type", (Fe_2O_3% is greater than CaO% + MgO%), the ash from the 5% ash product of most size fractions contains less iron than calcium plus magnesium and so must be characterized as "lignitic type". This change in character affects the interaction of other oxides and alters the significance of various factors in the assessment of ash behaviour.

The silica:alumina ratio is much less than 2:1 for the 50 x 25 mm fraction (1.22:1) and rises to just over 2:1 for the 6 x 1 mm fraction. Because of the content of other minerals, this does not have a direct correlation with fusion temperatures (they rise where the SiO_2/Al_2O_3 ratio indicates they should be falling) other than to make all temperatures, especially fluid temperatures, quite high.

Normally, for coal with "lignitic type" ash, the dolomite percentage (below) is used to indicate tendencies for fusion temperatures. The steadily dropping percentage towards finer sizes should be accompanied by lower fusion temperatures.

$$\text{Dolomite Percentage} = \frac{100 \times (CaO + MgO)}{Fe_2O_3 + CaO + MgO + Na_2O + K_2O}$$

The 5% ash product from each size fraction, however, has only marginally lignitic ash, and the character decreases steadily towards the finer size fraction until the 1 mm x 0 ash is marginally bituminous in type. The other parameter used to determine the appropriateness of application of the dolomite percentage is the content of acid components (SiO_2, Al_2O_3 and TiO_2). All of the size fractions exceed the maximum 60% cut-off.

The most significant parameter for judging (and explaining) trends in fusion temperatures is the base:acid ratio:

$$\text{Base:Acid} = \frac{Fe_2O_3 + CaO + MgO + Na_2O + K_2O}{SiO_2 + Al_2O_3 + TiO_2}$$

From the 50 x 25 mm fraction, the ratio drops steadily from 0.19 to a minimum of 0.12 in the 6 x 1 mm fraction. There is a slight rise again in the 1 mm x 0 (to 0.15). This corresponds exactly with the rise in fusion temperatures from coarse to fine fractions and the levelling off below 1 mm. In absolute terms, the base/acid ratio (consistently below 0.25) indicates that melting temperatures should be high and slagging tendency very low, an observation borne out by the actual fusion temperature measurements.

Because of the "lignitic type" character of the ash, the influence of sodium content on the fouling potential of the coal is much reduced. The presence of a greater relative proportion of calcium is thought to have moderating effect on sodium accumulation and, therefore, a content of less than 2% is considered very favourable in a lignitic ash. The content of chlorine as measured through the interference of heavy liquid contribution is also satisfactorily low (less than .2%). Below 6 mm, the fineness of the material causes much greater absorption and retention of float/sink fluid and these values are entirely unreliable (See Tables 5.9, 5.10 and 5.11).

5.6 10% Ash Product Quality

The same fine size fractions discussed in the 5% ash product section (5.5) were also cleaned in a separate procedure to assess their product potential at 10% ash. Many of the trends noted for the 5% ash products also apply to the 10% ash products but there are also some interesting differences, particularly in ash mineral composition and behaviour.

5.6.1 Proximate, Sulphur, Calorific Value, H.G.I.

The tendency for moisture values to be high in coarse fractions because of moisture retention in larger particles, lower in the middle range of size fractions because of the greater surface area to mass ratio in this range, and then higher again in fine size fractions because of the higher content of persistently moist clays in the ash, is quite clearly defined in the 10% ash fractions. In these products also, the moisture values initially measured by standard procedures were very high (up to 6%) and they were remeasured using the more carefully controlled technique described previously (Section 5.4.1). All other proximate and ultimate factors affected by moisture were adjusted as per the new values and are reported on Tables 5.14 through 5.18. The moisture in the coarser fractions is around 1.5%, dropping to 1.0% in the 6 x 1 mm fraction and rising again to 2.0% in the 1 mm x 0 fraction.

There is some fluctuation around the target ash from size to size; values range from 9.5% up to 10.3%. Yields are very good through all fractions above 1 mm and illustrate the influence of liberation from the 50 x 25 mm fraction (80.4% yield) to the 6 x 1 mm fraction (92.7% yield) with a steady increase in between. Liberation in cleaning is not the only relevant factor, as the head ash of the 6 x 1 mm fraction is also the lowest of all size fractions. The high head ash of the 1 mm x 0 fraction, partly through liberation of fine ash material from the coarser fractions (see Section 5.4.1) contributes to its relatively low yield of 46.8% (at 9.9% ash).

The volatile matter content of the 10% ash products is not influenced by contribution from ash material to a significantly greater extent than that of the 5% ash products. This interference by ash does not come into play until higher ash levels are reached. For the size fractions from 50 mm down to 1 mm, volatiles are in the range of 5.1% to 5.7%. These values are actually lower than those reported for the 5% ash products, but this is a function of the correction calculation from the initial measured moisture to the later (lower) residual moisture. True values for volatiles at true residual moisture will be very similar for 5% and 10% ash products. The effect of the high clay content of the 1 x 0 mm ash is demonstrated again by a drastically inflated "apparent" volatile level (9.2%).

Fixed carbon levels are largely a function of ash content through all fractions down to 1 mm. To this point the range is between 83% and 84%. In the 1 mm x 0 fraction, because of the high volatile control, a reading of only 78.9% is recorded.

Calorific values are quite consistent at 7300 cal/gm (gross) or slightly above for most size fractions. The gross calorific value for the 6 x 1 mm fraction is lower (7220 cal/gm.) because the ash level is slightly higher. The value for the 1 mm x 0 fraction is even lower as some heat is internally absorbed in the breakdown of ash material (see Section 5.5.1).

There is no significant variation in sulphur values through all size fractions (0.4 - 0.5%).

The Hardgrove Grindability Index is marginally higher in the 10% ash products than in the 5% ash products. It is comparable in all fractions down to 6 mm (31 to 33) and then rises in the finer fractions (37 in the 6 x 1 mm and 49 in the 1 mm x 0). Again, the readings in the finest fractions may not be as accurate as for coarser fractions due to the abundance of fine particles already in the sample prior to grinding.

5.6.2 Ultimate Analysis

The ultimate analysis is the measurement that indicates the greatest consistency between the coals of the different size fractions. Proximate analysis can be altered in some degree, as has been seen, by peculiarities of the ash contained within the coal. The hydrogen and nitrogen levels in the ultimate analysis should not be affected unduly by the ash constituents and for the 10% ash products, these two measures are most constant. Hydrogen values are 2.4% to 2.6% through all size fractions and nitrogen ranges from 0.7% to 0.9%. The carbon level more or less reflects fixed carbon; 80.5% to 82.3% down to 1 mm, and 77.7% for 1 mm x 0, and the oxygen levels are subject to the same influence as the volatiles at 2.9% - 3.7% down to 6 mm, 4.3% for the 6 x 1 fraction and rising to 6.8% in the 1 mm x 0 fraction.

5.6.3 Ash Fusion and Ash Mineral Analysis

Much the same trends exist for the ash fusion temperatures in the 5% and 10% ash products. There is a general rise in temperatures from the coarsest to the finest size fractions. The span between initial and fluid temperature in an oxidizing atmosphere appears to remain about the same, (200°C), though below the 12 x 6 mm fraction the fluid temperature exceeds the maximum calibrated temperature for the fusion furnace. In a reducing atmosphere, the fluid temperature also rises but the initial temperature appears to decrease. In the 50 x 25 mm fraction, the range (in a reducing atmosphere) is 1250°C - 1490°C (initial to fluid, a span of 240°C). For the 1 mm x 0 fraction the range is 1215°C - 1540°C, a span of at least 325°C. The result of these tendencies taken jointly is that the span between temperatures in an oxidizing and reducing atmosphere increases as the size decreases. Fluid temperatures in both atmospheres are near or in excess of 1540°C for all fractions, but initial temperatures span 55°C (1305°C oxidizing and 1250°C reducing) for the 50 x 25 mm fraction and 160°C (1375°C oxidizing and 1215°C reducing) for the 1 mm x 0 fraction.

As mentioned earlier, the differences between ash minerals compositions in the 5% and 10% ash products are intriguing. Where the ash of most of the 5% ash products (down to 6 mm) is "lignitic type" (Fe_2O_3% is less than MgO% + CaO%) and then a transition to "bituminous type" (the reverse situation) occurs, in the 10% ash products the transition is much earlier. Only the 50 x 25 mm fraction has "lignitic type" ash. Below 25 mm, the ash becomes propressively more bituminous in character. The same trend in silica:alumina ratios seen in the 5% ash products occurs with the exceptions that the ratios are, in general, much higher (and the fusion temperatures, therefore, lower), and the peak comes in the 12 x 6 mm fraction rather than in the 6 x 1 mm fraction.

Silica contents are also higher than in the 5% ash products at 52.4% for the 50 x 25 mm fraction, rising to peak at 62.0% in the 12 x 6 mm fraction, and dropping again to 57.1% in the 1 mm x 0 fraction. Alumina contents describe exactly the opposite variation going from 26.8% to 23.2% to 26.8%, respectively.

The apparent discrepancy between the peaking of various mineral contents in the 12 x 6 mm fraction and the peaking of fusion temperatures in the 6 x 1 mm fraction (although the fluid temperature remains high, both hemispherical and softening temperatures drop off again in the 1 mm x 0 fraction) lies in the interaction of the base:acid ratios and the silica:alumina ratios. The base:acid ratio declines quite steadily between 50 x 25 mm fraction (0.16) and the 12 x 6 mm fraction (0.12) and the fusion temperatures, in consequence, rise. The base:acid ratio stays the same in the 6 x 1 mm fraction (0.12) but the silica:alumina ratio, having peaked in 12 x 6 mm fraction, is slightly lower. Ash fusion temperatures, therefore, are the highest of all in the 6 x 1 mm fraction.

In absolute terms, the slagging tendency for all fractions, as indicated by the base:acid ratio is very low (always less than the standard of 0.5 for bituminous type ash, and less than 0.25 for lignitic type ash). The fouling factor is also satisfactorily low (uniformly less than 0.25) even though the sodium levels are somewhat high (more than 0.5%) in cases where the ash is of bituminous type (anything less than 3.0% is considered very favourable in a lignitic ash).