FLATHEAD RIDGE COAL AREA SOUTHERN DOMINION COAL BLOCK (PARCEL 82) SOUTHERN BRITISH COLUMIBA*
(82G/7)

By D. A. Grieve and W. E. Kilby

INTRODUCTION

The Dominion Coal Block consists of two parcels of federally owned land, totalling 20 235 hectares in area, in the Crowsnest Coalfield of southeastern British Columbia (*see* Grieve and Kilby, 1985). Parcel 82 is the more southerly of the two, and at 18 211.5 hectares (45,000 acres) it is by far the larger (Fig. 2-1).

The coal-bearing Kootenay Group crops out on two major areas of Parcel 82: along Flathead Ridge in the southwest and in the Mount Taylor area in the northeast; it lies at depth beneath the intervening portion. The subject of this study is the Flathead Ridge portion of the parcel, which is bounded on the northwest by Morrissey Creek (Fig. 2-1).

Flathead Ridge runs in a general northwest-southeast direction at an elevation of 1 980 to 2 225 metres. It has a steep scarp face on its southwestern flank (up to 70 per cent grade) and a relatively gentle slope on its northeastern flank. Minimum elevation in the study area is 1 070 metres along Morrissey Creek. The only readily accessible part of the study area is Morrissey Creek, which is connected to Highway 3 by approximately 5 kilometres of good-quality secondary road. Difficult four-wheel drive access to the top of Flathead Ridge is available on the natural gas pipeline access road, which connects with the Lodgepole forestry road.

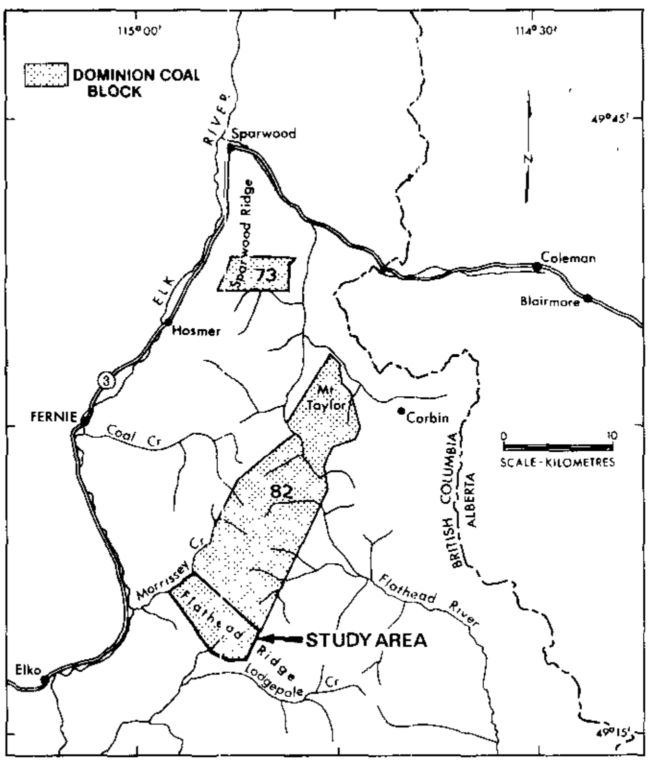

Figure 2-1. The Crowsnest Coalfield area, showing locations of Parcels 73 and 82 of the Dominion Coal Blocks.

OBJECTIVES OF PRESENT STUDY

The objectives of the current study are: to construct a digital deposit model of the Flathead Ridge to allow resource calculations of A- and B-seam coal utilizing existing data supplemented by minor fieldwork; and to summarize available exploration and production history, stratigraphy, structure, and coal quality information.

We have chosen to concentrate on these upper seams because exploration carried out in the study area focused on this stratigraphic interval and provides adequate information for a reasonable analysis. Also, the structure of the lower seams is more complicated and not well explored.

PREVIOUS WORK

Crow's Nest Pass Coal Company operated the Morrissey Colliery immediately north of Morrissey Creek, outside of Parcel 82, between 1902 and 1909. This was the shortest lived of the three collieries developed by the company at the turn of the century. The reasons for its early demise were hazardous mining conditions and poor coking properties of the coal due to its high rank.

There is no evidence of major exploration activity south of Morrissey Creek prior to 1964. At that time the British Columbia-based Pacific Coal Limited (P.C.L.) acquired coal rights to the Flathead Ridge portion of Parcel 82, naming their property the Fernie Coal Mine. The company was funded by Japanese interests; their objective was to prove up reserves of low-volatile coking coal for the Japanese steel industry. The first year of exploration, supervised by consultant D. D. Campbell, was focused on the Morrissey valley. Ten diamond-drill holes, totalling approximately 1 675 metres, were drilled. This program continued into 1965 with the completion of two more holes (300 metres). This information is not on file with the Provincial Government. Further work in 1965 was carried out by Nittetsu Mining Consultants Co., Ltd. Adits were driven for bulk samples in two of the lower seams (K1 and K5) along Morrissey Creek, and surface mapping was carried out along Flathead Ridge. A preliminary feasibility study was completed at this time. Exploration work in 1966 and 1967 was concentrated on A- and B-seams. By this time P.C.L. had acquired coal rights to a 7 458-hectare area, and the scale of exploration increased considerably. Work was performed by Nittetsu Mining Co., Ltd. and Toyo Menka Kaisha, Ltd. Seven drill holes were cored for a total of 1 599 metres, nine adits in A- and B-seams were driven and sampled, and more than 29 kilometres of new road was built; most roads were along the traces of A- and B-seams. Detailed mapping, supplemented by trenching, was carried out over the entire property. Drill core and bulk samples were provided to several Japanese steel concerns for testing of washability and coking potential.

The general conclusions of this assessment work were that B-seam throughout the property and A-seam locally are superior

* This project is a contribution to the Canada/British Columbia Mineral Development Agreement.

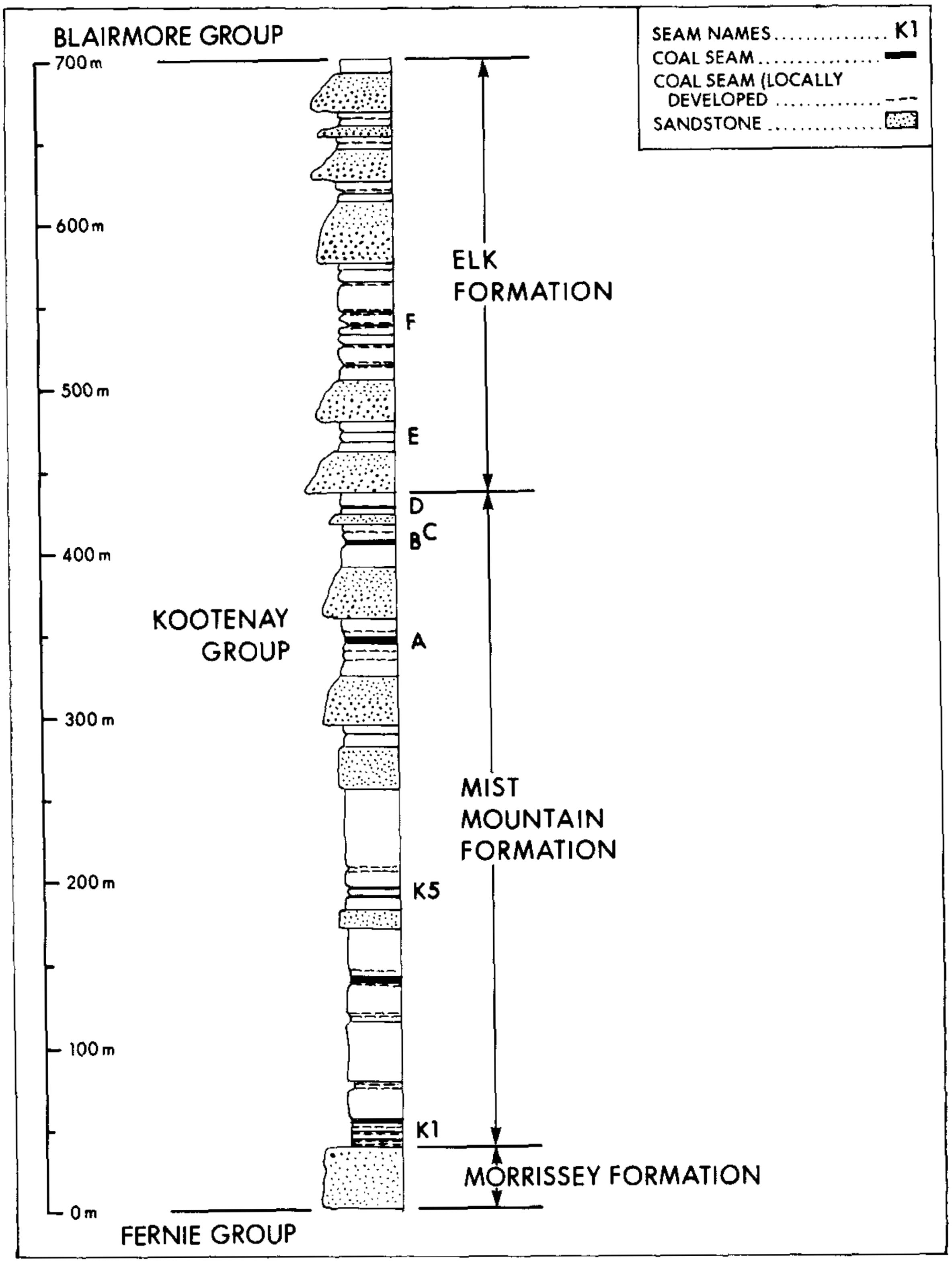

Figure 2-2. Generalized composite stratigraphy of the Kootenay Group in the study area (modified after Aihara, 1970).

coking coals, and that they are present in significant quantities. A 1968 feasibility study by Nittetsu for P.C.L. reiterated that the coal was economically mineable and equal to other western Canadian coking coals contracted to Japan at the time. In 1968 or 1969, however, Nittetsu withdrew from the project and Mitsui Mining Co., Ltd. obtained permission from P.C.L. to further evaluate the property. In 1969 they carried out a geological survey, aided by trenching. A few differences in structural interpretation and seam correlation were noted. Further exploration was proposed but never carried out. In 1971-1972 the Provincial Government, at the request of the Federal Government, revoked the coal rights.

Results of the exploration projects carried out between 1965 and 1969 are contained in the following reports: Nakayama, *et al.* (1966), Harada, *et al.* (1967, 1968), and Aihara (1970). Results of the 1968 feasibility study are contained in Shiokawa (1968). All are on file with the Geological Branch of the British Columbia Ministry of Energy, Mines and Petroleum Resources. Individual reports will not be specifically referenced in the following discussions.

Two government surveys of the study area were carried out in the late 1970's. Between 1977 and 1980 N. C. Ollerenshaw of the Geological Survey of Canada mapped all of Parcel 82 at 1:50 000 scale (*see* Ollerenshaw, 1981b). D. E. Pearson and D. A. Grieve of the British Columbia Ministry of Energy, Mines and Petroleum Resources mapped Flathead Ridge in 1978 at 1:10 000 scale, concentrating on the surface traces of coal seams (*see* Pearson and Grieve, 1981, Sheets 3 and 4). In conjunction with this mapping, coal samples were collected for petrographic analysis.

STRATIGRAPHY

Flathead Ridge is underlain by a sequence of sedimentary rocks belonging to the Jurassic Fernie Group, Jurassic-Cretaceous Kootenay Group, and Lower Cretaceous Blairmore Group. Marine shales of the Fernie Group are in gradational contact with the overlying littoral Morrissey Formation, basal sandstone of the Kootenay Group. Morrissey Formation is abruptly overlain by the non-marine coal-bearing Mist Mountain Formation, host to economic coal seams in southeast British Columbia. This in turn is gradationally overlain by the Elk Formation, a non-marine unit which contains thin coal seams and a higher proportion of channel sandstones and conglomerates than the underlying Mist Mountain (Fig. 2-2). The Elk is overlain by the non-marine Cadomin Formation, basal unit of the Blairmore Group. The Cadomin Formation in the study area consists of a series of conglomerates separated by maroon and greenish mudstones (Ollerenshaw, 1981a). It is overlain by greenish and maroon mudstones interbedded with sandstone and conglomerate of the Lower Blairmore.

There are two readily identified marker horizons within the study area. One is the Morrissey Formation, whose outcrops form a relatively consistent bluff; the Morrissey marks the lower limit for coal occurrences (Fig. 2-2). The other is the Cadomin Formation, which delineates the top of the Kootenay Group. The contact between the Mist Mountain and Elk Formations, which probably represents the transition from a meander plain to a braid plain environment (Gibson, 1985), is usually defined as the lowest channel deposit above the highest economic coal seam in the Mist Mountain Formation. This horizon can be mapped with some certainty throughout the study area.

The Mist Mountain Formation is approximately 400 metres thick in the study area and on average it contains 10 coal seams. Seams were numbered upward from K1 to K5, and then A, B, and so on (Fig. 2-2). Initial quality results on seams K1 and K5 from Morrissey Creek revealed that the rank of these seams was too high to be attractive. This led the company to focus on two more promising seams, A and B, in the upper half of the Mist Mountain Formation (Fig. 2-2). A-seam underlies B-seam by 25 to 45 metres. In outcrop it ranges from 3.5 to greater than 15 metres total thickness at the northwestern end of the ridge (No. 3 to No. 8-9 ridges); it is from 2.6 to 7.7 metres thick at the southeastern end (TA-2 to Ridge No. 21; *see* Fig. 2-3 for location references). Between it is less than 1.6 metres thick with numerous partings. In drill core thicknesses range from 2.68 (J-6) to 17.77 metres (J-3). Lower splits of A-seam exist in the area southeast of Ridge No. 17. The upper of these (A1) ranges from 2.34 to 3.05 metres in thickness, while the lower (A2) ranges from 1.82 to 3.36 metres; both appear to be increasing in thickness to the southeast. Thickness of A-seam coal ranges from 60 to 100 per cent of total seam thickness, but is generally greater than 90 per cent, omitting the central area mentioned previously. The AL-seam is located just below the A-seam in the northwest portion of the area. AL-seam thickness ranges from 2.0 to 6.0 metres.

B-seam thickness ranges in outcrop from 1.73 to 5.86 metres and in drill core from 3.64 metres (J-2) to 7.32 metres (J-3). An upper split, named BU-seam, outcrops on Ridge No. 11 and extends southeastward; it ranges from 1.25 to 2.51 metres in thickness. Thickness of B-seam coal is generally greater than 80 per cent but ranges from less than 60 to 100 per cent of the total seam thickness.

Both A-seam and B-seam are characterized by rapid thickness changes and variations in the numbers and thicknesses of partings.

Seam K1 (basal seam) ranges from 3.06 metres in thickness at the pipeline, to greater than 15 metres in Morrissey Creek. Seam K5 has a thickness of greater than 5 metres in Morrissey Creek area, but unfortunately the company was not successful during exploration in correlating this or other lower seams with seams along the ridge. Thicknesses of other coal seams were measured only locally, but available data suggests that in the vicinity of the pipeline and the pipeline road (Ridge Nos. 16 to 20), the section between seams K1 and A contains three coal seams which are greater than 1 metre in thickness. The thickest of these, which apparently lies within 20 metres stratigraphically of the top of the K1 seam, is reported to be 6.52 metres thick on Ridge No. 20, and includes a 3.47-metre section of coal without partings at the top. Pearson and Grieve (1981, section L-M) also report a 5.1-metre seam about 115 metres above the base of the Mist Mountain Formation on Ridge No. 16. Coal seams stratigraphically higher than B-seam are thin, although again data are sparse. Pearson and Grieve (1981, section L-M) found three closely spaced seams with a combined total thickness of 5.8 metres near the top of the section on the pipeline (Ridge No. 16). The equivalent (?) horizon on Ridge No. 3 contains a 3.27-metre seam with 2.68 metres of coal.

The Nittetsu reports concluded that seam K1 probably sustains thickness adequate for mining throughout Flathead Ridge; they speculated that two or three other seams are thick enough for mining, at least locally.

STRUCTURE

Flathead Ridge is in the southwestern part of the Crowsnest Coalfield. The Fernie Basin, the coalfield's fundamental structure, is a complex synclinorium in the Front Ranges of the Rocky Mountains. Strata on Flathead Ridge lie in the west limb of the McEvoy syncline, a doubly plunging fold at the middle of the south end of the Fernie Basin.

Ollerenshaw (1981b) notes a regional décollement or 'preferred detachment interval' within the Mist Mountain Formation. The strata below this interval are affected by 'tight, low amplitude folds of relatively short wavelength, cut by numerous thrust faults,' while those above are characterized by 'broader, gentle folds of low amplitude and relatively long wavelength cut by fewer thrust faults but numerous normal faults' (Ollerenshaw, 1981b, p. 147). Within the study area this décollement occurs below A-seam and was identified as the Flathead Ridge normal fault by Pearson and Grieve (1981, Sheet 3) and the Morrissey Retrothrust by Ollerenshaw

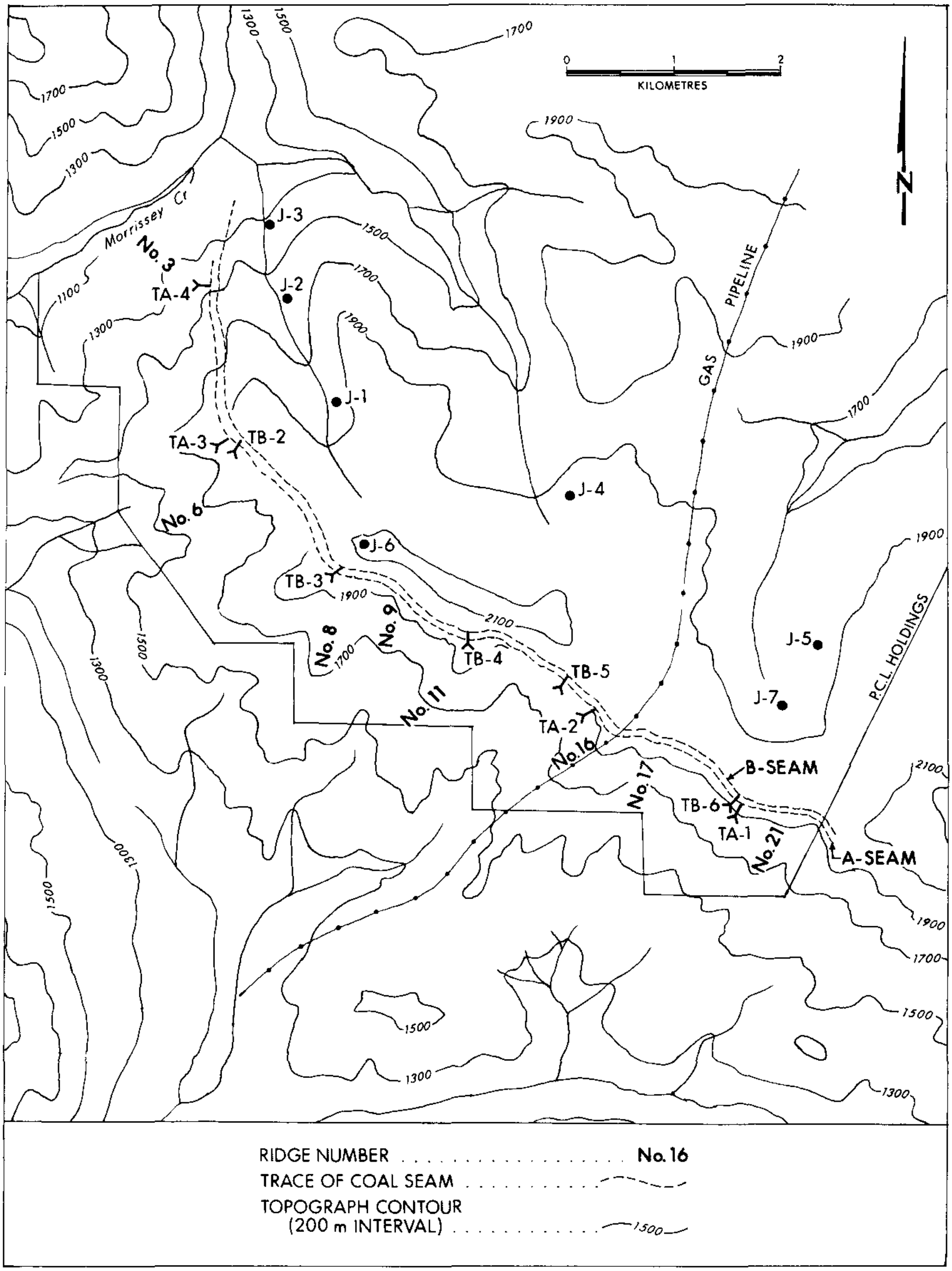

Figure 2-3. Flathead Ridge area, showing traces of A and B-seams, 1966-1967 drill hole locations, adit sites, ridge numbers, and southeastern boundary of P.C.L. holdings (after Aihara, 1970).

TABLE 2-1
COMBINED RESULTS OF FLOAT-SINK TESTS (B-SEAM)*
(Source: Mitsui Report)

Raw Coal Ash (%)	23.2	23.2	23.2
Clean Coal Ash (%)	7.0	8.0	9.0
S.G. (g/cc)	1.53	1.60	1.68
Calculated Yield (%)	70.0	75.0	77.0
Revised Yield** (%)	65.0	70.0	72.0

* based on samples TB-2, TB-3, TB-4, and TB-6
** allowing 5% dilution during mining

(1981b). Both studies cited traced the fault from Morrissey Creek southeastward along the face of Flathead Ridge to a point roughly halfway between the creek and the southeastern boundary of Parcel 82 (Fig. 2-3). Ollerenshaw (p. 151) speculated that the fault continues through to the boundary, but is hidden in bedding of the Mist Mountain Formation. Pearson and Grieve concluded that the fault changes orientation suddenly, cuts rapidly up section, and affects the continuity of A- and B-seams; in the present study no field evidence was found to support this interpretation and the interpretation of Ollerenshaw has been adopted. Disturbances in strata in the vicinity of A- and B-seams are considered to be local in extent.

The structure of the upper Mist Mountain Formation and higher strata on Flathead Ridge is monoclinal. On the southwest face of the ridge average strike of strata is 130 degrees with dips of 20 degrees northwest. In the area behind (northeast of) the ridge line, the strike is the same but the dip flattens to 10 degrees northwest. Minor structures include predominantly small-scale, low displacement northeast-dipping thrust and normal faults.

In contrast, strata beneath the Morrissey fault are intensely folded; fold-axes trending northeast-southwest, and the strata are also affected by northeast-dipping thrust faults.

COAL QUALITY

Extensive tests of Flathead Ridge coal were carried out by up to six prospective purchasers in Japan. Results are summarized in following text.

WASHABILITY

Float-sink tests of bulk samples were performed in conjunction with both the Nittetsu and Mitsui studies. Data in Table 2-1 are summarized from the latter source, and deal with B-seam only. Results from samples TB-2, 3, 4, and 6 were combined. Yields were calculated on the assumption that the plus 0.5-millimetre fraction would be washed with heavy medium cyclones and the minus 0.5-millimetre fraction by froth flotation. As Table 2-1 shows, yields of 70.0, 75.0, and 77.0 per cent are calculated based on clean coal ash contents of 7.0, 8.0, and 9.0 per cent respectively. Allowing 5 per cent dilution during mining, the yields reduce to 65.0, 70.0, and 72.0 per cent respectively.

STEEL MILL TESTS

Six Japanese steel mills were provided with cleaned bulk samples for testing; the results recorded in the Nittetsu reports were later reproduced in the Mitsui report. Summaries for A- and B-seam samples are displayed in Tables 2-2 and 2-3.

Clean B-seam has average volatile matter contents ranging from 23.3 to 19.2 per cent, decreasing from southeast (TB-6) to northwest (TB-2). Lowest Free Swelling Index (FSI) values (6.5 to 7.5) are associated with TB-2, while other sites tend to be in the 8.0 range. Lowest average fluidity also occurs at TB-2 (48 dial divisions per minute) with the highest being at TB-4 (708 ddpm). Sulphur values are in the 0.5 per cent range, and heating values are near 33.5 MJ/kg. Drum index values are all above 92 per cent. The Nittetsu report concludes that B-seam is a superior coking coal.

Clean A-seam has average volatile matter contents ranging from 21.2 to 17.5 per cent, decreasing from southeast (TA-1) to northwest (TA-4). FSI at 3 to 4.5 and fluidity values are low at TA-3 and TA-4 relative to TA-1, where FSI is 6 to 7.5. Sulphur and calorific values are very similar to those of B-seam. Drum index values are low at TA-3 and TA-4, but are equivalent to B-seam at TA-1. The conclusion was drawn that superior quality coking coal could be found in the southeast end of the ridge, but that coal at the northwest end is semi-coking coal. Unfortunately TA-2 results were not reported. It was suggested that A-seam from the northwest might be blended with B-seam from the central or southeast part of the ridge to increase reserves of acceptable quality coking coal.

Two other seams, K1 and K5, were bulk sampled at Morrissey Creek. Clean coal volatile matter content of K1 averaged 14.4 per cent at 8.5 per cent ash, while those of K5 averaged 16.1 per cent at 8.8 per cent ash. FSI values of K1 ranged from 3 to 4, while those of K5 ranged from 3.5 to 5. Heating values of K1 averaged 32.85 MJ/kg, and those of K5, 32.64 MJ/kg. Average drum indices of 54.2 and 84.6 per cent respectively were obtained. This material appears to be potential semi-coking coal at best; it might be better described as thermal coal, especially in the case of K1.

RANK DISTRIBUTION

The Japanese survey reports conclude that the tendency of clean coal volatile matter contents and related coking properties to decrease from southeast to northwest (toward Morrissey Creek) in all seams represents a definite trend in carbonization. This trend, or

TABLE 2-2
SUMMARY OF TEST RESULTS AT JAPANESE STEEL MILLS (A-SEAM)*

Sample	Moist %	Ash %	Volatile Matter %	Fixed Carbon %	S %	Kcal/kg	FSI	Drum Index (+15mm)	Fluidity (ddpm)
TA-1	1.3 (avg)	4.5	21.2	73.0	0.41	8 178	6-7.5	91.9	47
	1.0-1.5 (range)	4.15-4.8	20.75-21.8	72.0-73.6	0.38-0.42	8 060-8 322		89.9-94.4	1.95-225
TA-3	1.1	6.5	20.0	72.8	0.28	8 017	3.5-4	58.0	6
	0.8-1.4	6.4-6.6	19.5-20.9	71.3-73.9	0.27-0.29	7 900-8 230		50.0-63.9	2.4-9
TA-4 Upper	1.2	6.6	17.4	74.8	0.45	7 965	3-4.5	49.1	11
	0.8-1.4	6.4-6.8	17.2-17.7	74.4-75.0	0.41-0.50	7 930-7 990		36.0-70.2	1.48-20
TA-4 Lower	1.2	5.8	17.5	75.6	0.36	8 027	3-4.5	44.2	4
	0.8-1.4	5.1-6.3	17.4-17.6	74.9-76.7	0.34-0.40	8 010-8 050		(only value)	1.6-7

* washed coal

TABLE 2-3
SUMMARY OF TEST RESULTS AT JAPANESE STEEL MILLS (B-SEAM)*

Sample	Moist %	Ash %	Volatile Matter %	Fixed Carbon %	S %	Kcal/kg	FSI	Drum Index (+15mm)	Fluidity (ddpm)
TB-6	1.8 (avg)	6.8	23.3	68.4	0.48	7 985	7.5-8.5	93.9	186
	1.7-1.9 (range)	6.7-7.2	22.3-24.06	67.8-69.21	0.44-0.56	7 900-8 070		93.0-95.4	66-412
TB-5	1.3	6.3	21.0	71.8	0.50	8 070	8-9	94.0	336
	1.2-1.17	6.1-6.73	20.1-21.71	71.3-72.1	0.48-0.53	7 990-8 140		93.5-94.8	206-758
TB-4	1.3	6.8	21.9	70.3	0.40	8 013	8-9	94.3	708
	1.1-1.5	6.6-6.9	21.3-22.8	70.0-70.5	0.38-0.42	7 930-8 080		93.3-94.9	390-1235
TB-3	1.5	6.2	20.6	72.0	0.50	8 077	7-8	94.0	98
	1.3-1.7	6.0-6.4	20.2-20.91	71.6-72.74	0.49-0.52	7 950-8 220		93.4-94.4	52-220
TB-2	1.1	7.0	19.2	72.7	0.57	7 993	6.5-7.5	92.8	48
	0.6-1.4	6.4-7.9	18.4-20.1	71.9-73.2	0.54-0.60	7 890-8 090		91.4-94.7	2.9-113

* washed coal

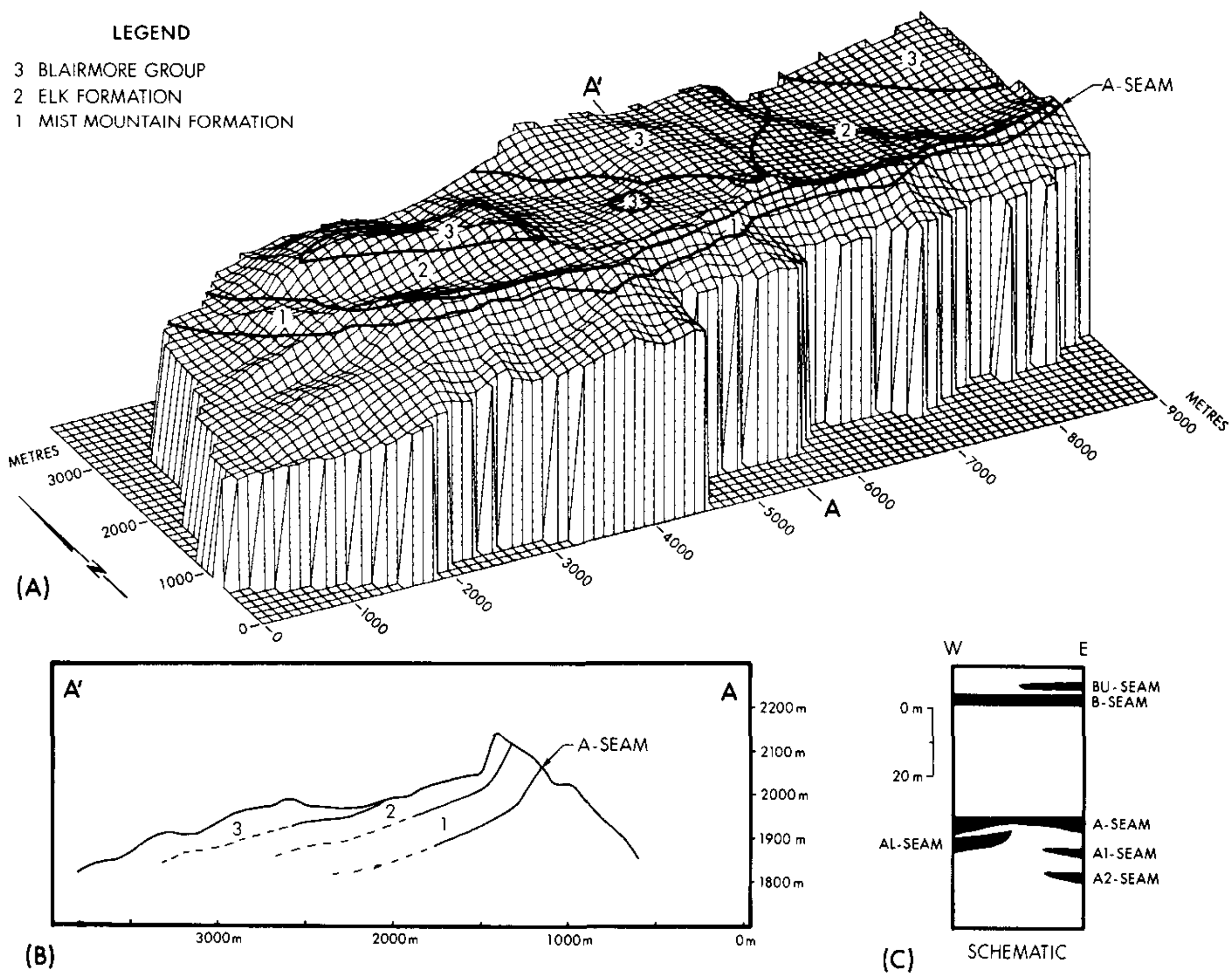

Figure 2-4. (a) Isometric display of model topography with major geological contacts illustrated. (b) Vertical cross-section displaying the shape of the ridge crest; subsurface geology is approximate. (c) Schematic display of seams described by the model.

rank gradient, is corroborated by the work of Pearson and Grieve (1981, 1985). Vitrinite reflectance values from coal samples collected in the field are highest at the north end of Flathead Ridge at Morrissey Creek; they decrease in both directions along strike. Rank values in the Morrissey Creek section are further enhanced by down-dip increases noted in the Crowsnest Coalfield (Pearson and Grieve, 1985). The net result is that essentially the entire Mist Mountain section at the level of Morrissey Creek contains coals of low-volatile bituminous rank ($\bar{R}_o$ max>1.51 per cent). A value of 1.85 per cent was obtained on the basal seam on Ridge No. 3, near the K1 adit. $\bar{R}_o$ max decreases to 1.71 per cent for the same horizon at the base of Ridge No. 6, and to 1.62 per cent in the vicinity of the pipeline. In other words, at least some portion of outcropping Mist Mountain Formation is low-volatile in rank throughout the length of the study area, and with rank values increasing down-dip in all cases.

Reflectance in A- and B-seams ranges from approximately 1.3 per cent at the southeast end of the property, to 1.4 per cent on Ridge No. 6, to greater than 1.5 per cent in the Morrissey Creek valley. Therefore, these seams are predominantly medium-volatile bituminous at their outcrop locations, except at the extreme northwest end of the property where, because the elevation is low, outcrops are down-dip extensions of those along the ridge. The high rank of coal in Morrissey Creek was a major contributing factor to the permanent closure of the Morrissey Colliery in 1909, and is an important factor to consider here. Remember that A-seam is not a good quality coking coal at adits TA-3 or TA-4 (or in drill hole J-3). B-seam appears to maintain its quality as far as adit TB-2 (and drill hole J-1), but unfortunately there are no sample locations north of TB-2, and drill hole J-2 did not intersect B-seam. Results of testing of B-seam in J-3 were not reported.

PROPOSED MINING METHOD

The feasibility report of the Pacific Coal Limited property by Nittetsu Mining Co., Ltd. was submitted at the end of four years of exploration. The underground mining plan envisaged the main mine entrance to be at elevation 1 160 metres on the southeast side of Morrissey Creek, with the main level developed along the strike of the seam. Longwall mining was selected as the most feasible method to exploit the dip of the seams (10 to 20 degrees) and to ensure maximum recovery, ventilation, and productivity. The property is very close to rail; the proposed mine entrance described here, for example, is less than 6 kilometres east of the Canadian Pacific Railway line. Normal annual production rate was projected to be 1 million tonnes. The Mitsui interim report based its revised recoverable reserve calculations on the assumption that room-and-pillar mining would be utilized where possible, that is, where the dip was sufficiently low, presumably in the lowest, most northeast portion of the mine.

COMPUTER DEPOSIT MODEL

The Flathead Ridge area was modelled using the grid surface technique in which each deposit characteristic of interest is represented by a grid of values covering the whole deposit. A variety of techniques were employed to construct the digital surfaces depending upon data characteristics. This section of the paper discusses data collection, grid building, and deposit model analysis. Software utilized in this project were the Data Handler and Grid Handler modules of Cal Data Ltd.'s Geological Analysis Package, which was donated to the Geological Branch.

The first step in the modelling procedure is to select the size of area to be modelled, the resolution, and the orientation of the model grid. In this study a 90 by 39 rectangular grid consisting of 100-metre grid squares was constructed which covers 35 square kilometres (Fig. 2-4). Due to the orientation of the strata (130 degrees), the grid was oriented northwest-southeast, so grid north is actually 41 degrees east of north. A new coordinate system was used during modelling; it was parallel to the model grid with the origin in the southwest corner of the grid. Once the size and shape of the model were selected, the required information was entered into the computer and corresponding surfaces calculated. The objective of this model was to determine coal tonnages and their distribution within the study area. To arrive at these answers the following parameters were entered and/or described by grid surfaces:

(1) topographic position,
(2) seam elevations,
(3) seam thicknesses,
(4) seam areal positions, and
(5) distances from nearest data points to each grid mode.

The following section discusses determination of the grid surfaces for each of these parameters.

Topographic data was collected from an existing 1:5000-scale contour map with 5-metre contour intervals which was provided with the Harada, *et al.* (1968) report. A digitizing tablet connected to an IBM XT was utilized for this function. Data was digitized along lines through the centre of the columns of the model grid; data was recorded wherever a significant (to define all breaks in slope) contour crossed the line. The values at the centres of each of the model grid squares was then determined by linear interpolation between data points along the digitized lines. The advantages of this method are that a high degree of accuracy is obtained for the grid values, and the raw data is retained in a format that is useable if grid square sizes are changed. The disadvantage is that data collection is labour intensive, requiring about 16 hours of digitizing effort in this case. The resultant grid was stored in Grid Handler format.

Seam positioning within the deposit is the most complex problem of most modelling exercises. First the geology of the deposit must be solved, then the configuration of the seams digitially represented and stored.

Data used for this purpose were bedding orientation and seam position in outcrops, boreholes, trenches, and adits. Outcrop orientation data was collected by means of the digitizing tablet with the COD (Coal Outcrop Digitizer) program developed by one of the authors (W. E. Kilby). The resultant information consisted of an outcrop identifier, easting and northing coordinates, elevation, dip direction and dip of strata, formation code, and type of measured feature. This data was then stored in Data Handler format. Borehole, trench, and adit data were collected manually from the various reports. Seam name, position of the seam top, coal thickness, and information source type were recorded for each seam encountered in a trench, adit, or borehole. In addition, the collar and end of hole positions were recorded for boreholes. Six seams were incorporated into this model. Two seams, A and B, are found throughout the entire model area. The other four seams, AL (A lower), BU (B upper), A1, and A2, are of limited extent (Figs. 2-4c and 2-6).

B-seam, the upper of the two continuous seams, was positioned first because it was described by the largest number of well-spaced data points. A down-plunge projection technique was used to arrive at the digital surface describing the position of the top of the B-seam (*see* Gold, *et al.*, 1981). Figure 2-5a is a profile section oriented normal to projection direction, it shows the positions of all B-seam data and the pitch lines of outcrop orientation data. The initial projection orientation was obtained by interpreting outcrop orientation data on a pi-diagram. The projection direction should be parallel to the fold-axis or 90 degrees away from the maximum concentrations of the poles to bedding. After initial selection of the projection direction, minor orientation adjustments were made on a trial and error basis to minimize the scatter of B-seam data points. Upon selection of the best projection orientation, which was 30 degrees trend with 0 degree plunge, the position of the seam was

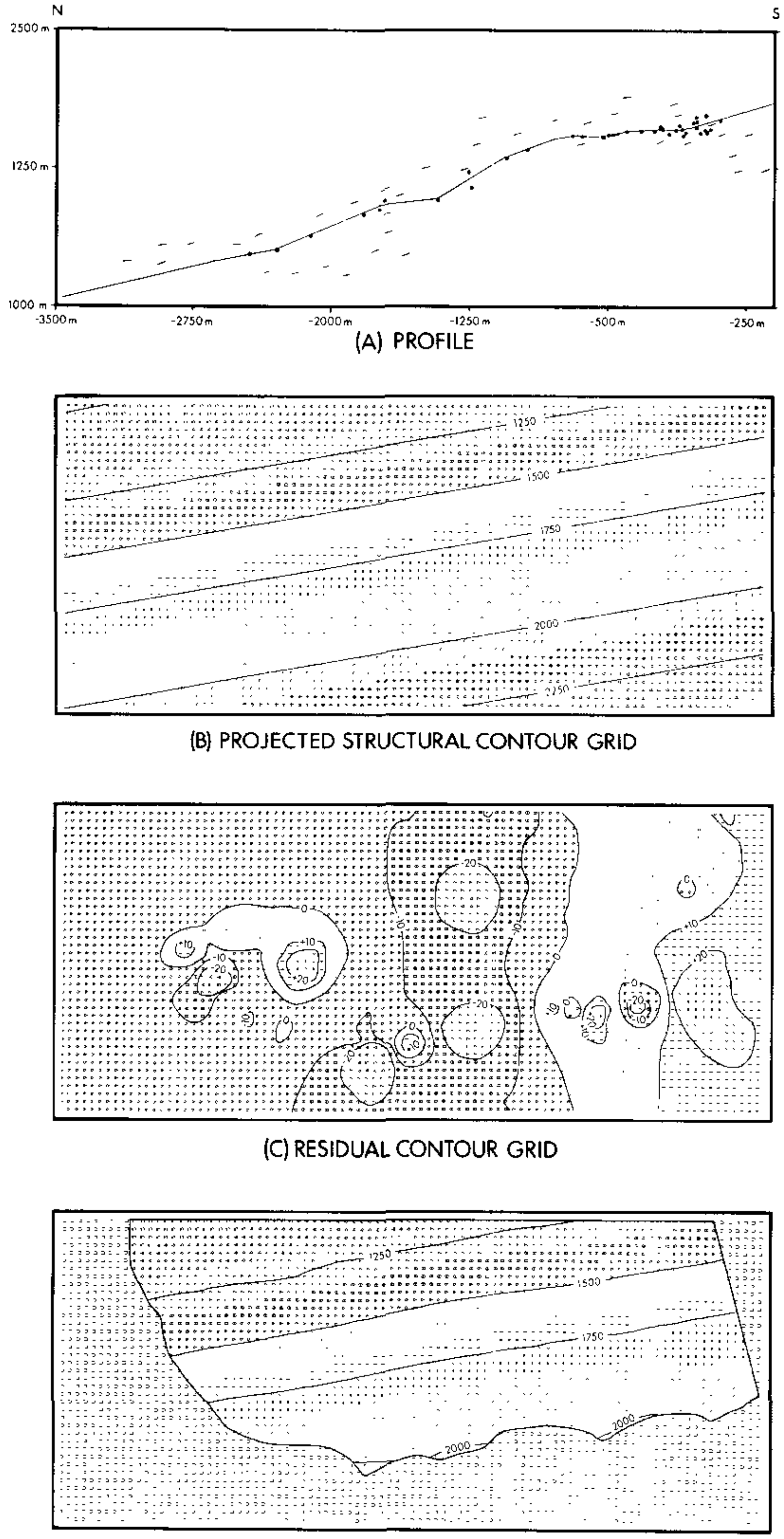

Figure 2-5. (a) Down-plunge projection profile of B-seam data (dots) and selected outcrop orientation data (pitch lines). Interpreted B-seam position also shown. (b) B-seam structural contour grid obtained by projecting interpreted B-seam position line from (a) parallel to the projection direction. (c) Residual grid, obtained by gridding the difference between B-seam positional data and the B-seam structural contour grid. (d) Final B-seam position grid obtained by subtracting the residual grid from the grid displayed in (b). This grid has been trimmed at outcrop and property boundaries.

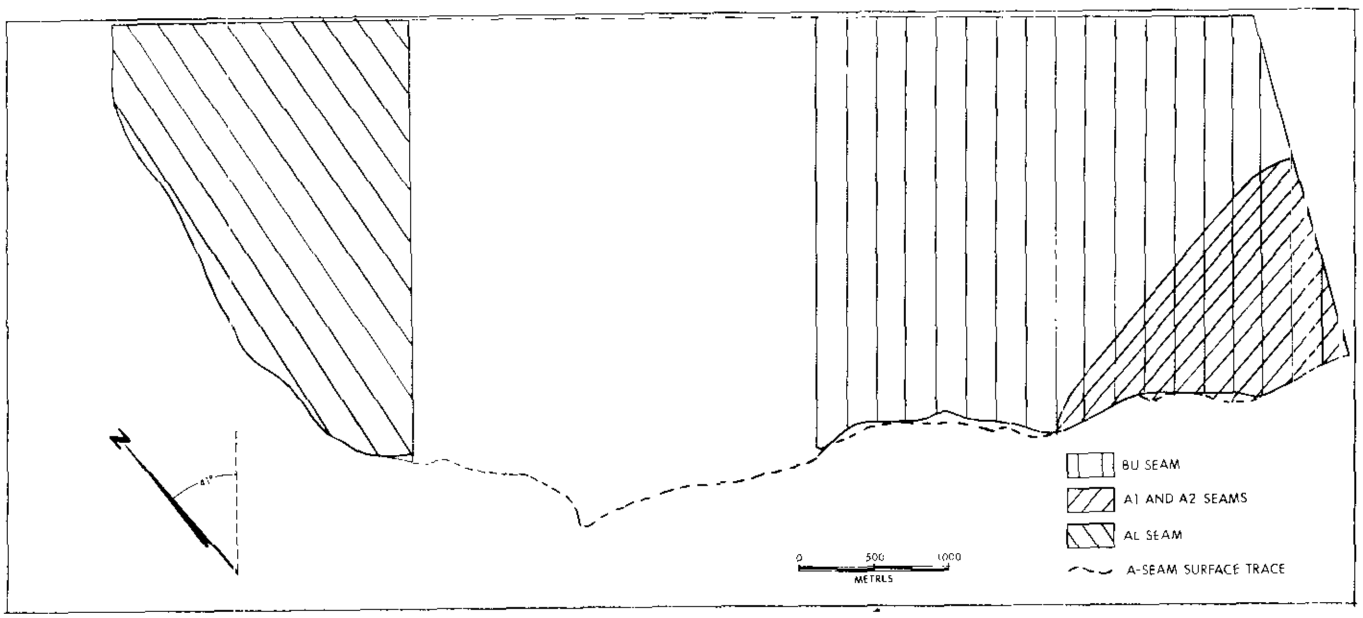

Figure 2-6. Areal distribution of seams used in the digital deposit model. A and B-seams are found over the whole area with only minor differences in outcrop traces.

manually traced onto the profile. This line was then digitized and projected parallel to the selected projection direction so that its position at each grid centre could be calculated. The result was a surface which had the cross-sectional shape of the seam trace on the profile and oriented parallel to the projection direction (Fig. 2-5b). This surface reflects the general structure of the seam but, because it is artificial, does not necessarily coincide with any of the B-seam data. To solve this problem a residual grid was constructed and added to the down-plunge projection (dpp) grid. The residual grid was calculated by an inverse distance squared weighting, moving average algorithm. The raw data for this calculation is the difference in elevation between the actual data position and the position contained in the ddp grid (Fig. 2-5c). The grid used to make evaluation calculations was generated by adding the residual grid to the dpp grid; this resulted in a surface which retains the authors' interpretation of the general structure but also honours all data points (Fig. 2-5d).

A-seam was positioned by determining a grid of A-seam to B-seam distances and subtracting this grid from the B-seam position grid. Only four widely spaced boreholes provided useable information for this purpose. A grid was constructed from these raw data by the inverse distance squared ($1/d^2$) moving average technique.

Once these two seam position grids were determined, they were trimmed by removing those grid squares which represented seam positions above the topographic surface.

The four minor seam position grids were obtained in a similar manner except that constant inter-seam interval thicknesses were used for each seam. These interval thicknesses were + 1, − 1, − 8, and − 16 metres for B-BU, A-AL, A-A1, and A-A2 respectively. The same outcrop trim lines were used for these minor seams as for the associated continuous seams, which is acceptable due to the steepness of the ridge face and the scale of the model.

Seam thickness grids for all the seams were obtained by a $1/d^2$ moving average algorithm. Total coal thickness within seams rather than actual seam thicknesses were used in these calculations. Semi-variograms were determined for the thickness data, but due to the limited number and poor distribution of data points these plots were of little use. The method used actually results in a smooth version of results obtained by the polygon method. In one borehole an exceedingly thick B-seam intersection of 17.11 metres was arbitrarily reduced to 10 metres as it was felt that this anomalous thickness was not depositional, but due to local structure and should not influence too great an area of the model. Some trench data did not expose the entire seam and thicknesses were reported as a value followed by a '+' sign. Only the reported thickness values were used, thus seam thickness values are on the conservative side.

A series of grids or templates, which mark the area of the model underlain by each seam, were constructed. These template grids contained a '1' in each grid point underlain by the seam and a '0' in areas where the seam was not present (Fig. 2-6). The A- and B-seams were only absent in areas where the seams were removed by erosion. The four minor seams had subsurface terminations in addition to the erosional terminations.

Finally a series of grids containing the distance to the nearest data point from each grid square centre for each seam were constructed. These grids are used to categorize tonnage values because geostatistical parameters such as those in Kilby and McClymont (1985) were unobtainable; the quality of the raw data was inadequate to define these parameters (Fig. 2-7).

Upon completion the Flathead Ridge model contained 37 digital surfaces describing the five deposit variables selected. Additional surfaces describing other parameters could be added to the model.

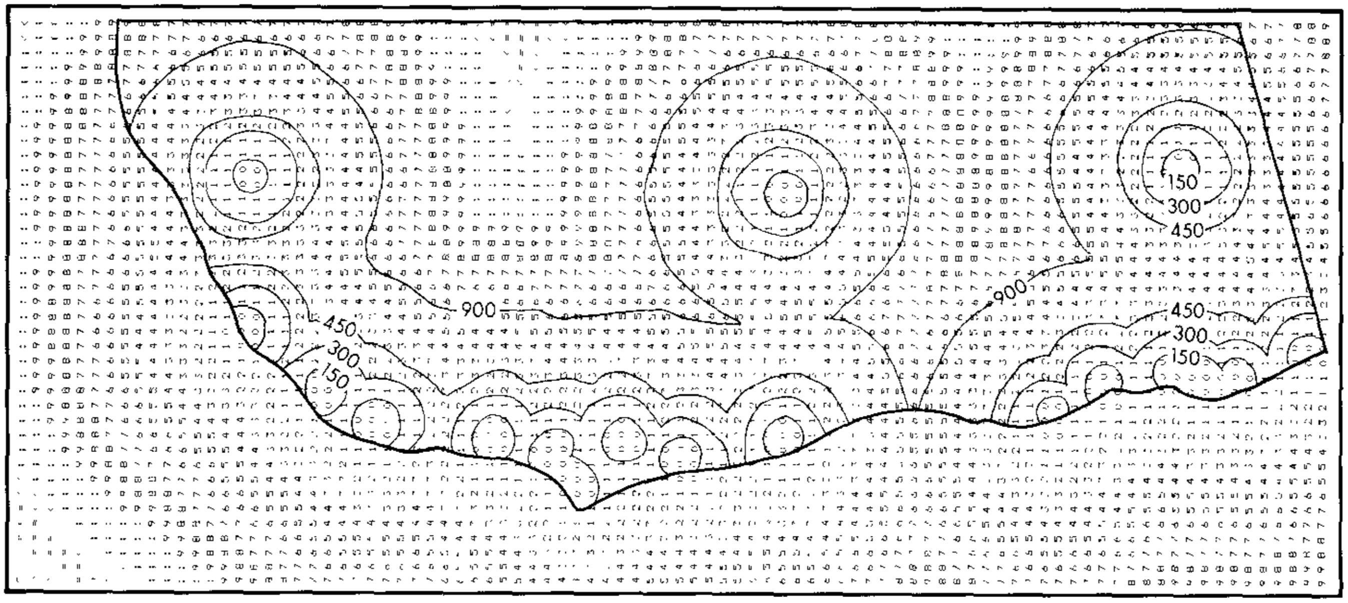

Figure 2-7. B-seam distance grid, showing the minimum distance to the nearest data point.

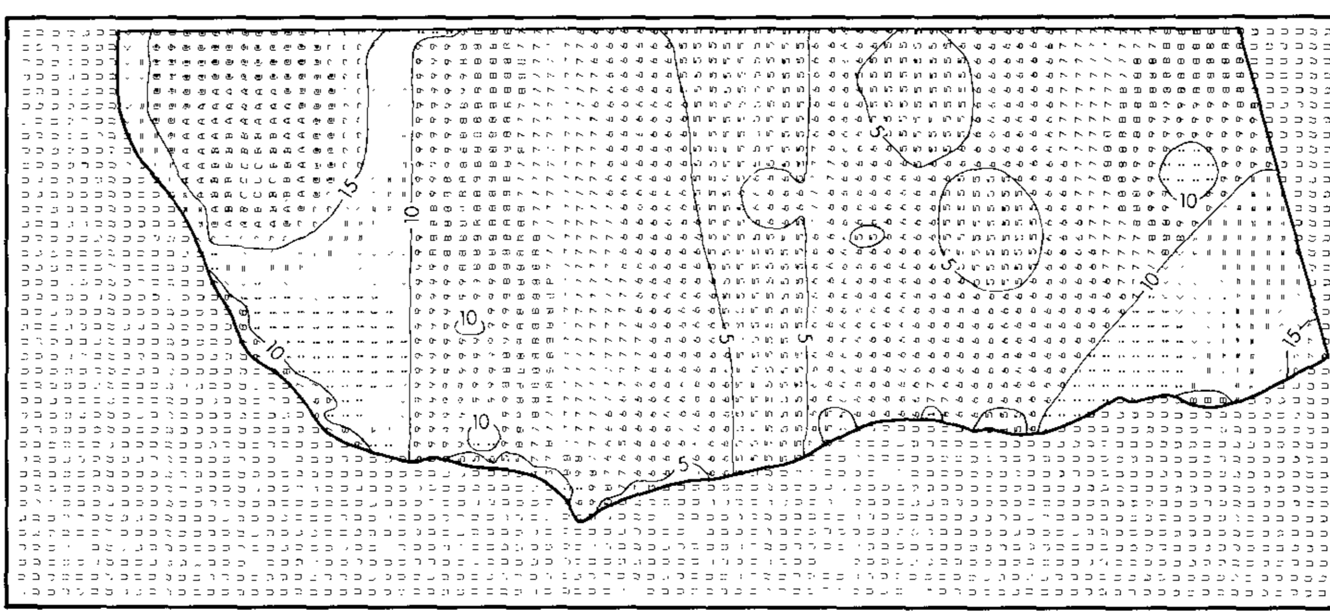

Figure 2-8. Total coal grid shows the distribution of total coal thickness from the six seams used in the model.

MODEL ANALYSIS

The digital model describes coal seam position, thickness, and distance from the nearest data point within the study area. As such it can be used to answer a variety of questions related to the coal resources. The following section describes the techniques used to extract these answers from the model and presents some of the results.

How much coal is in the deposit in the various confidence categories? To answer this question the seam thickness grids for each seam were assessed. Coal thickness values at each grid square which fell within the acceptable boundaries contained in the template grids, and which fell within a specified distance from the nearest data point, contained in the distance grids, were summed. A minimum seam thickness of 1.3 metre was used in these calculations. The three distance intervals which were selected to correspond with the categories of measured, indicated, and inferred were 0 to 150 metres, 150 to 300 metres, and greater than 300 metres respectively. A coal specific gravity of 1.3 g/cc was used in the calculations; each grid square was 100 by 100 metres, therefore there would be 13 000 tonnes per vertical metre of coal per grid square. The results of this calculation are presented for each seam in Table 2-4.

TABLE 2-4
RESERVES AND RESOURCES, FLATHEAD RIDGE

Seam	Measured (Tonnes)	Indicated (Tonnes)	Inferred (Tonnes)	Total (Tonnes)
A	6 286 130	12 815 100	86 778 000	105 879 000
AL	1 023 340	3 253 450	17 920 200	22 197 000
A1	673 532	1 067 230	3 283 410	5 024 170
A2	634 593	1 052 550	3 472 390	5 159 530
B	8 390 460	11 628 200	69 645 700	89 664 300
BU	463 211	351 411	1 040 260	1 854 880
Total	17 471 266	30 167 941	182 139 960	229 778 880

Where is the coal? This question was answered by constructing a total-coal map. This procedure required only summing all the seam thickness grids. The result is a map of coal thickness over the deposit (Fig. 2-8).

What is the vertical waste-to-coal ratio distribution, that is, is there any open pittable material? To answer this query two preliminary sets of information were required: total coal distribution, and total waste material distribution over the area. The total coal distribution was determined in the preceding section. Total waste is the amount of material between the topographic surface and the base of the lowest mineable seam less the total thickness of coal in the interval. At each grid point the lowest coal seam present was determined from the seam elevation grids. The thickness of the seam at that position was then subtracted from the seam top elevation to obtain the lowest elevation to be considered at each grid centre. This value was then subtracted from the corresponding topographic elevation stored in the topography grid. The resulting waste-to-coal grid obtained was a map of the vertical ratio of the volume of rock to the volume of coal (Fig. 2-9). To convert these data to the more conventional bank cubic metres (BCM) per tonne of coal, one multiplies by the inverse of the coal specific gravity. As seen from this map, there are 2.85 square kilometres of Parcel 82 with vertical volume ratios of less than 10 to 1; these areas are found at either end of the study area. However, additional drilling would be required to confirm these ratios because some seam positions were obtained by projections over significant distances.

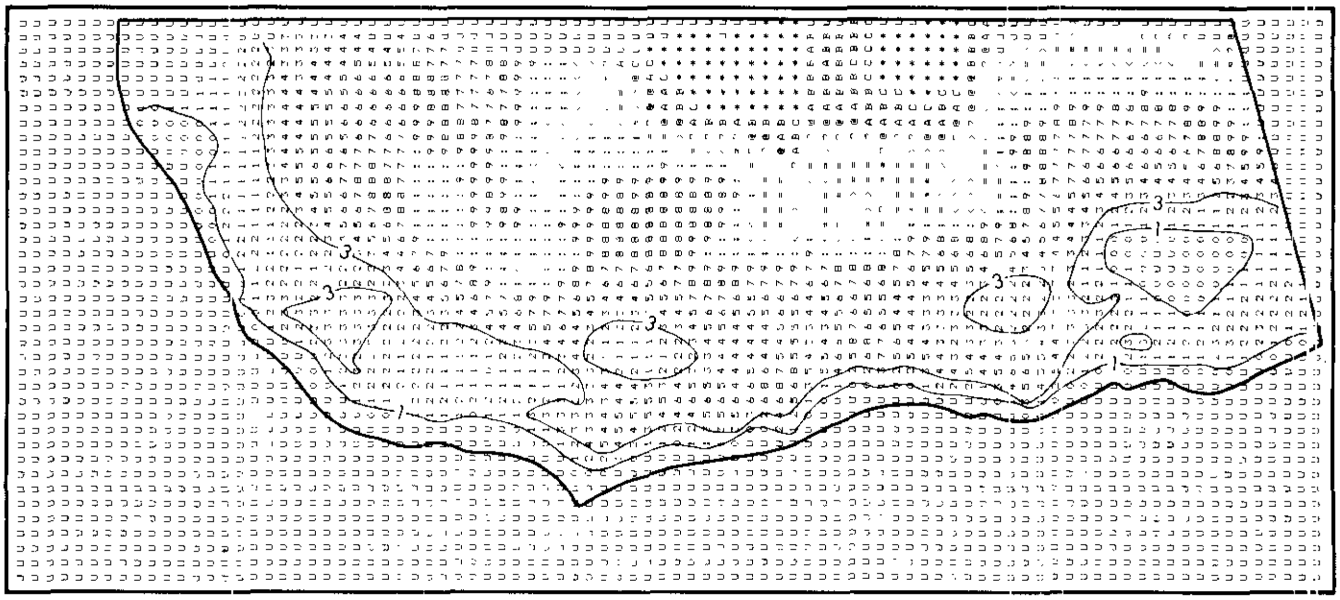

Figure 2-9. Waste-to-coal ratio map shows the distribution of the vertical ratio of non-coal to coal in the area.

CONCLUSION

The model is based on limited poorly distributed data, yet the study indicates that the Flathead Ridge area contains considerable coal resources. Significant tonnages of this coal may already be placed in the measured and indicated categories as defined by Energy, Mines and Resources Canada and the British Columbia Ministry of Energy, Mines and Petroleum Resources. In addition, several portions of the area hold significant volumes of medium to low-volatile coal that could be extractable by open pit methods. The area is well situated with respect to infrastructure.

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