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GORDON D. WILLIAMS
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DEEP COAL RESOURCES OF THE INTERIOR PLAINS, ESTIMATED FROM PETROLEUM BOREHOLE DATA

Abstract

Thick Cretaceous and Tertiary coal measures extend widely across the Canadian Interior Plains east of the Rocky Mountain Foothills. Coal seam depths and thicknesses and their containing stratigraphic units were picked in nearly 4000 petroleum exploration boreholes distributed uniformly over an area of approximately 385 000 sq. km in Manitoba, Saskatchewan, Alberta and British Columbia. Seam data were assigned to one of five reliability index categories based on completeness of the suite of logs available and curve character on individual logs. The greatest proportion of seam intersections (>90%), the thickest seams (>12 m), and the greatest seam depths (>3000 m) occur in Alberta. No coal was found in Manitoba.

Seams were placed in one of four groupings for purposes of mapping and quantity estimation: thick seams (≥2 m) with reliability index categories 1 and 2 (>80% probability of occurrence), thick seams with reliability index categories 3 to 5 (<55% probability of occurrence), thin seams (<2 m thick) with reliability index categories 1 and 2, and thin seams with reliability index categories 3 to 5. In each of these four groupings, measured resources are estimated at between 5000 and 10 000 megatonnes, indicated resources between 16 000 and 30 000 megatonnes and inferred resources between 1 300 000 and 2 300 000 megatonnes. These amounts are larger than any previous recent estimate by factors of up to several orders of magnitude.

More than 90 per cent of the resources occur in Alberta with most of the remainder in Saskatchewan and a small amount in British Columbia. More than half of the coal occurs in the Mannville Group and equivalent strata of Early Cretaceous age with the remainder in Late Cretaceous strata of the Judith River and Edmonton Formations.

Résumé

A l'est des Foothills des montagnes Rocheuses, d'épaisses couches de charbon d'âge Crétacé et Tertiaire couvrent de vastes étendues à travers les plaines Intérieures canadiennes. On a exploré la profondeur et la puissance des couches de charbon et de l'unité stratigraphique encaissante, au moyen de presque 4 000 sondages pétroliers uniformément répartis sur environ 385 000 km² au Manitoba, en Saskatchewan, en Alberta et en Colombie Britannique. D'après l'intégralité de la série de diagraphies obtenues et le caractère des courbes données par les diagrammes disponibles, on a placé les données relatives aux couches de charbon dans l'une de 5 catégories d'indices de fiabilité. C'est en Alberta que l'on rencontre la plus forte proportion d'intersections de couches (>90%), les couches les plus épaisses (>12 m) et les plus profondes (>3 000 m). Au Manitoba, on n'a pas découvert de charbon.

Aux fins de cartographie et d'évaluation des quantités, on a placé les couches dans l'un de 4 groupes: des couches épaisses (≥2 m) dans les catégories 1 et 2 d'indices de fiabilité (probabilité de présence >80%); des couches épaisses dans les catégories 3 à 5 (probabilité de présence <55%); les couches minces (<2 m) dans les catégories 1 et 2; et les couches minces dans les catégories 3 à 5. Dans chacun de ces quatre groupes, on estime que les ressources mesurées sont comprises entre 5 000 et 10 000 mégatonnes, les ressources indiquées entre 16 000 et 30 000 mégatonnes, et les ressources supposées entre 1 300 000 et 2 300 000 mégatonnes. Ces valeurs surpassent toutes les estimations récemment formulées, de parfois plusieurs ordres de grandeur.

Plus de 90% des ressources sont localisées en Alberta, presque tout le reste en Saskatchewan et une petite partie en Colombie Britannique. Le groupe de Mannville et les strates équivalentes du Crétacé inférieur contiennent plus de la moitié du charbon, les strates des formations de Judith River et d'Edmonton (Crétacé supérieur) renferment le reste.

INTRODUCTION

Rationale for Project

Coal-bearing strata of Cretaceous and Tertiary age are well known and widely distributed in the Plains area of western Canada, both in outcrop and in the subsurface. Except for the work of Yurko (1976), estimates of the quantities of coal reserves and resources contained in these strata have been based upon what could be seen at the surface and in mines or inferred from shallow exploration and development drilling in areas where mining has been carried out (see Latour and Chrismas, 1970; Alberta Energy Resources Conservation Board, 1977, 1979; Irvine et al., 1978; Bielenstein et al., 1979). Significant additional quantities of coal should be present in the deeper subsurface where in some areas of the Plains the coal measures occur at depths of more than 3000 m. Thick coal seams are present and sufficiently widespread to be used as stratigraphic markers in petroleum exploration in parts of the Plains (for example in the Mannville Group in the Medicine River area west of Red Deer and in the Judith River [Belly River] Formation in the Keystone area of the Pembina oil field southwest of Edmonton). At the time this project was begun however, no systematic study had ever been made of the distribution or quantity of coal in the deep subsurface of the Plains on the basis of petroleum exploration drillhole data.

Apart from the scientific satisfaction derived from increasing our knowledge of the environment, such a study would contribute to a national coal inventory (Irvine and Williams, 1978) and could have potential economic ramifications. For example, one aspect of new coal-utilization technology involves the extraction of energy from deep and/or thin seams by partial combustion in place with recovery of the produced gases – "in situ" gasification – and it follows that knowledge of the quantities of potential resource available for such schemes is required before their contribution to Canada's energy supply can be properly assessed. Moreover, demonstrating that large quantities of coal exist in seams which are either too deep or too thin to be mined conventionally might well stimulate or accelerate development of new methods for their recovery or for extraction of their contained energy.

Chronological Development

Work on the project began in 1973 as part of a larger, multi-phase research program which included building and utilizing a computer data base to assist in the evaluation of lignite deposits in Saskatchewan (Irvine et al., 1978). Data were collected in 1973 and 1974, but as demands of the Saskatchewan lignite evaluation project increased from 1974 to 1977, work on this project was curtailed, not to be resumed until late in 1977 after the completion and publication of the final report on Saskatchewan (Irvine et al., 1978).

Computer Utilization

From the inception of the project, it was apparent that successful completion of the study and maximum future utilization of the information obtained required the use of computer techniques to manage and display the data collected and perform the calculations necessary to produce resource quantity estimates. In particular, relatively large amounts of numerical data would be collected and used repetitively to estimate, categorize and map resource quantities. Moreover, there was a very high probability of adding to the data in the future and revising the calculations and maps in response to changing economic and/or technological conditions.

Acknowledgments

Funding for this project was provided principally by the Department of Energy, Mines and Resources through a series of research contracts. The Department of Geology, University of Alberta provided working facilities and assisted with computer costs. The Alberta Research Council collaborated on collection of data for the province of Alberta.

We wish to record our appreciation to: B.A. Latour, for continuous assistance and guidance; R.B. Simpson who helped to obtain the initial funding; B. Krausert and J.R. Yurko who collected the data; D.W. Flint who programmed and supervised data input and verification of the data; and C.F. Stevens who wrote the computer programs for quantity estimation and categorization.

DATA COLLECTION AND PROCESSING

Collection

When the project was begun, it was estimated that more than 20 000 boreholes, penetrating 13 000 to 16 000 km of potentially coal-bearing strata, had been drilled in the search for oil and gas in the western Canadian Interior Plains. To reduce data collection to manageable proportions and yet cover the entire Plains area, it was decided to use only one borehole per township (approximately 93 km^2, 36 mi^2) selected on the basis of most complete penetration of the coal-bearing succession to the top of the Paleozoic and most complete set of geophysical logs. Data were collected from a total of 3994 boreholes (97 in Manitoba, 1049 in Saskatchewan, 2448 in Alberta and 400 in northeastern British Columbia). All data were recorded in feet and subsequently converted to metres.

In general, petroleum drilling samples from the continental, coal-bearing portions of the sedimentary succession in the Plains are not adequate to determine the positions and thicknesses of coal seams with any accuracy, although the presence of seams can usually be detected. Samples are usually not even collected from the Edmonton Group and equivalents, a major coal-bearing unit in the western Plains, and cores which intersect coal seams are virtually non-existent. As a consequence of these factors it was necessary to collect all data from geophysical logs of the boreholes selected. This procedure placed limitations on the reliability or certainty that a coal seam actually exists at any given position in a borehole, particularly when the borehole was drilled many years ago and only older logs are available, or if some or all of the better, modern coal-detection logs were not run in the borehole.

By government regulation, the upper part of a petroleum borehole (the surface hole) is drilled and cased before the main hole is drilled. Only in exceptional circumstances is the surface hole logged, and as a result there is normally no geological information available on the section behind the surface casing. Thus the depth to the base of the casing, which varies from about 50 to 100 m in Manitoba to over 300 m in the western Plains of Alberta, controls the minimum depth at which a seam could be identified in this study (hence, we use the term "deep coal" in the title of this paper).

The design of logging tools used in the petroleum industry and the scale of the logs used in this study (1 in = 100 ft and 2.5 in = 100 ft) limit the minimum detectable thickness of coal or non-coaly partings (which were excluded from the resource estimates) to about 0.3 m (1 ft). Operationally it was decided that "seams" must be separated by at least 10 ft of non-coaly strata.

Data on each seam were assigned to one of five "reliability index" categories at time of collection, depending on how certain the geologist collecting the data was that coal was actually present. These categories were based on the combination of logs run in the borehole and the response of each log type and were defined as follows:

Category 1

Must have at least one electrical log (spontaneous potential plus various resistivity curves) and other logs with at least two of the following specific curves:

a. natural gamma
b. acoustic velocity (sonic)
c. density
d. sidewall neutron or compensated neutron.

Curve characteristics are well defined and coal is indicated strongly on all curves (Figure 1).

Category 2

Logs as in 1 above, but curve characteristics not as well defined; most criteria indicate coal.

Category 3

Must have an electrical log as in 1, and at least one additional log with reasonably well-defined curve characteristics indicative of coal, or alternatively one log with good characteristics plus a seam in correlative position with reliability index of 1 or 2, in 3 or more adjacent (offsetting) wells.

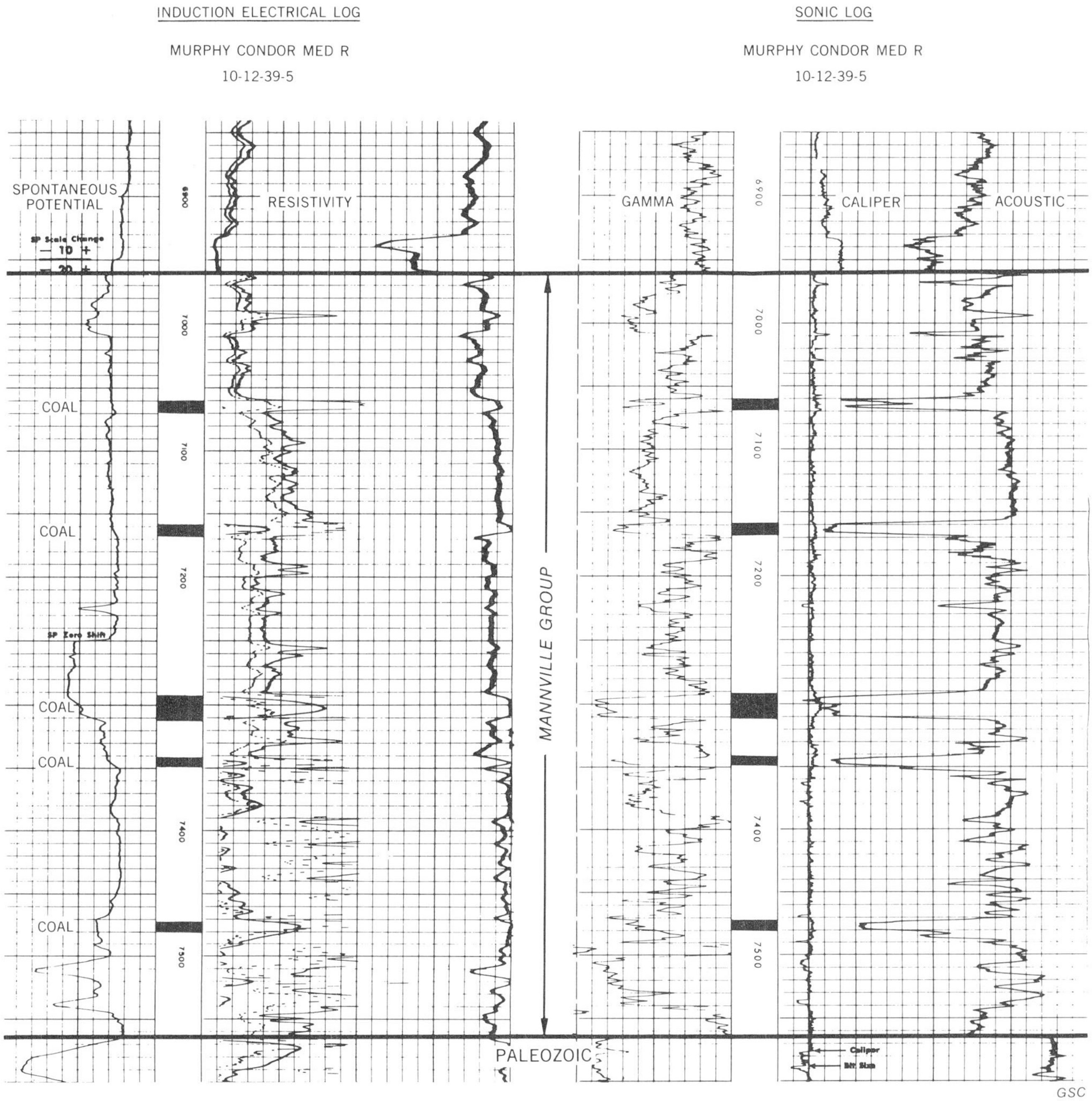

Figure 1. *Typical logs of borehole with seams of Reliability Index Category 1.*

Category 4

Logs as in 3 above but poorer in quality (old logs, poorly defined characteristics, etc.) with less strong indication of coal, or alternatively one log with poorer characteristics than in category 3, plus a seam in correlative position with reliability index of 1, 2 or 3 in 3 or more adjacent (offsetting) wells.

Category 5

Only one log present, or all logs of poor quality (Figure 2).

Samples from 265 boreholes in Alberta and Saskatchewan were examined to verify the presence of coal seams picked from geophysical logs. In Table 1 the number of seams identified in samples, reported as a percentage of those picked from logs in each reliability index category, is termed the probability-of-occurrence for that category and is a quantitative measure of the certainty that a seam picked from logs is actually present.

Considering the limitation on the accuracy of drilling samples discussed earlier, the authors consider these probability-of-occurrence values to be somewhat too low and indicate the minimum levels of confidence that can be placed on the data.

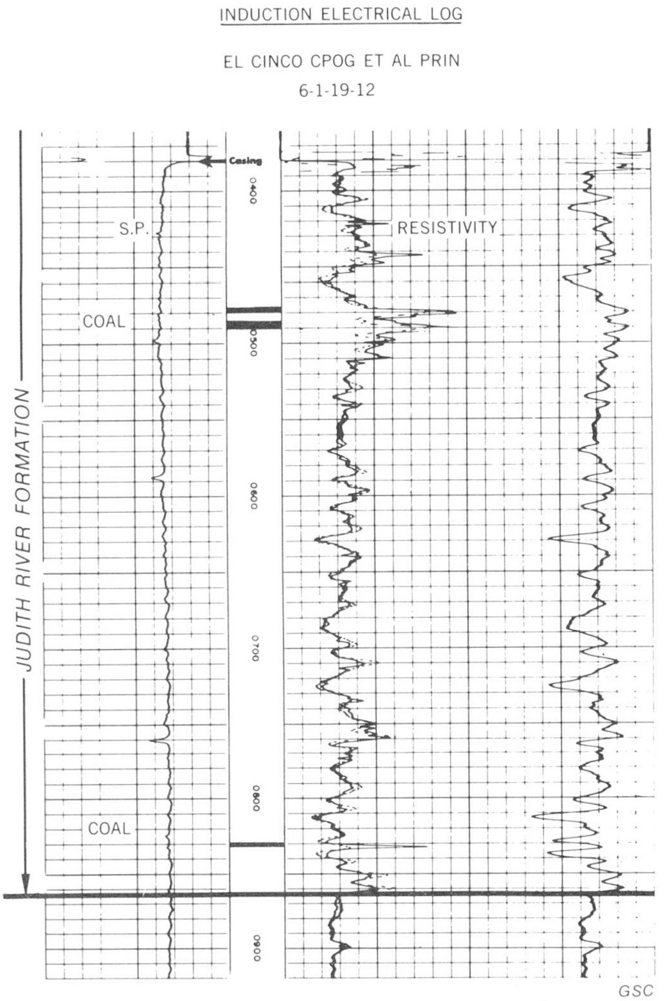

Figure 2. Typical log of borehole with seams of Reliability Index Category 5.

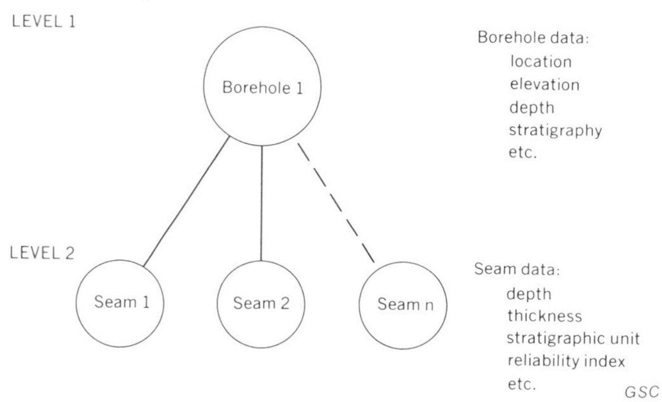

Figure 3. Schematic representation of the data base.

Processing

Computing facilities at the University of Alberta were used to manage and analyze the data. These initially consisted of an IBM 360/67 main computer which in 1975 was replaced by an AMDAHL 470V/6. Data management functions employed the SAFRAS, G-EXEC and MICRO systems, whereas mapping and analysis were carried out using SURFACE II, GPR and MIDAS. Computer programs written at the Institute of Sedimentary and Petroleum Geology were used to calculate and categorize quantities of coal in place as "measured", "indicated" and "inferred".

Table 1

Reliability Index Categories and probability of occurrence of coal seams

RELIABILITY INDEX CATEGORY	COAL SEAMS		PROBABILITY OF OCCURRENCE
	Picked on logs	Identified in samples	
1	228	182	80%
2	131	105	80%
3	64	34	53%
4	10	4	40%
5	37	9	24%

GSC

Data File Design

All data collected were fitted into a simple two level hierarchical system containing data pertaining to each borehole (including stratigraphic data) in the highest level and data pertaining to each seam encountered in the borehole in the second level. This structure is shown schematically in Figure 3.

GEOLOGY OF THE COAL MEASURES

Regional Setting

The area under study comprises much of the Interior Plains of western Canada, from the International Boundary north approximately to the Peace River in British Columbia, between the Canadian Shield on the east and the Disturbed Belt of the Cordillera on the west, a triangular region approximately 385 000 km^2 in area. Strata dip very gently to the south into the Williston Basin in Manitoba and southern Saskatchewan, and to the southwest into the Alberta Basin in Alberta and northeastern British Columbia (Figure 4). The coal measures consist of Cretaceous and Tertiary non-marine strata which lie unconformably above Paleozoic to Jurassic carbonates and clastic rocks, and extend to the present-day land surface where they are covered by a variable thickness of glacial deposits (McCrossan and Glaister, 1964).

Stratigraphy

The coal-bearing strata of the Interior Plains comprise the Lower Cretaceous Mannville Group, the Upper Cretaceous Judith River Formation and Edmonton Group and the Tertiary Paskapoo Formation (Table 2). The coal measures are relatively undeformed and regionally dip south and southwesterly towards the Williston Basin and the Cordilleran Deformed Belt (Figure 4). Their cover ranges from zero where glacial deposits are absent in parts of their outcrop areas to more than 3000 m beneath the western edge of the Plains (Figures 5 and 6).

The stratigraphic details of the coal measures in the Interior Plains have been discussed at length by many authors (Rudkin, 1964; Williams and Burk, 1964; Irish, 1970; Kramers and Mellon, 1972; McLean, 1971; Taylor et al., 1964).

RESOURCE ESTIMATION

Terminology

The quantities which have been calculated in this study are resources inasmuch as the technological and economic criteria which define reserves have not been taken into consideration. Moreover, they are "resources of future interest" (Bielenstein et al., 1979) according to the classification scheme adopted by the Department of Energy Mines and

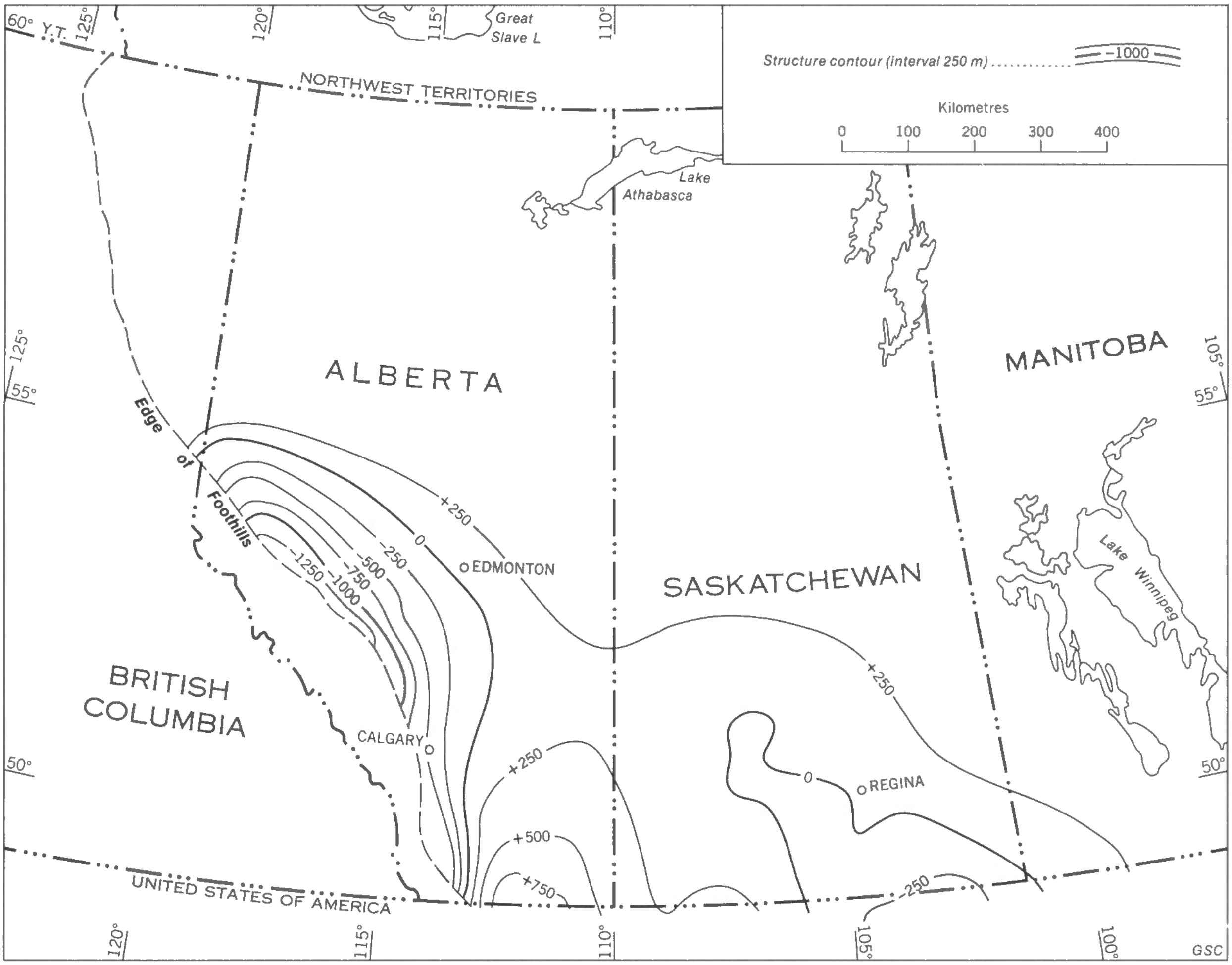

Figure 4. *Structure contours, top of Colorado Group (after Williams and Burk, 1964).*

Table 2

Stratigraphic terminology used

<table>
<tr><th></th><th>NE BRITISH COLUMBIA</th><th>CENTRAL ALBERTA</th><th>SOUTHERN ALBERTA</th><th>SOUTHERN SASKATCHEWAN</th><th>MANITOBA</th><th>This paper</th></tr>
<tr><td rowspan="2">TERT</td><td rowspan="2">PASKAPOO</td><td rowspan="2">PASKAPOO</td><td>PORCUPINE HILLS</td><td rowspan="2">RAVENSCRAG</td><td rowspan="4">BOISSEVAIN</td><td rowspan="2">PASKAPOO</td></tr>
<tr><td rowspan="2">WILLOW CREEK</td></tr>
<tr><td rowspan="8">UPPER CRETACEOUS</td><td rowspan="4">WAPITI</td><td rowspan="2">EDMONTON</td><td rowspan="2">FRENCHMAN
BATTLE
WHITEMUD
EASTEND</td><td rowspan="2">EDMONTON</td></tr>
<tr><td>ST. MARY RIVER</td></tr>
<tr><td>BEARPAW</td><td>BEARPAW</td><td>BEARPAW</td><td rowspan="2">RIDING MOUNTAIN</td><td>BEARPAW</td></tr>
<tr><td>BELLY RIVER</td><td>BELLY RIVER</td><td>JUDITH RIVER</td><td>JUDITH RIVER</td></tr>
<tr><td rowspan="3">SMOKY GROUP</td><td rowspan="2">LEA PARK</td><td>PAKOWKI</td><td rowspan="2">LEA PARK</td><td rowspan="3">VERMILION RIVER</td><td rowspan="2">LEA PARK</td></tr>
<tr><td>MILK RIVER</td></tr>
<tr><td rowspan="3">COLORADO GROUP</td><td rowspan="3">COLORADO GROUP</td><td rowspan="3">COLORADO GROUP</td><td rowspan="3">COLORADO GROUP</td></tr>
<tr><td>DUNVEGAN</td><td>FAVEL</td></tr>
<tr><td rowspan="3">LOWER CRETACEOUS</td><td rowspan="2">FORT ST. JOHN GROUP</td><td>ASHVILLE</td></tr>
<tr><td rowspan="2">MANNVILLE</td><td rowspan="2">'BLAIRMORE'</td><td rowspan="2">MANNVILLE</td><td rowspan="2">SWAN RIVER</td><td rowspan="2">MANNVILLE</td></tr>
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GSC

After Rudkin, 1964, Williams and Burk, 1964 and Taylor et al., 1964

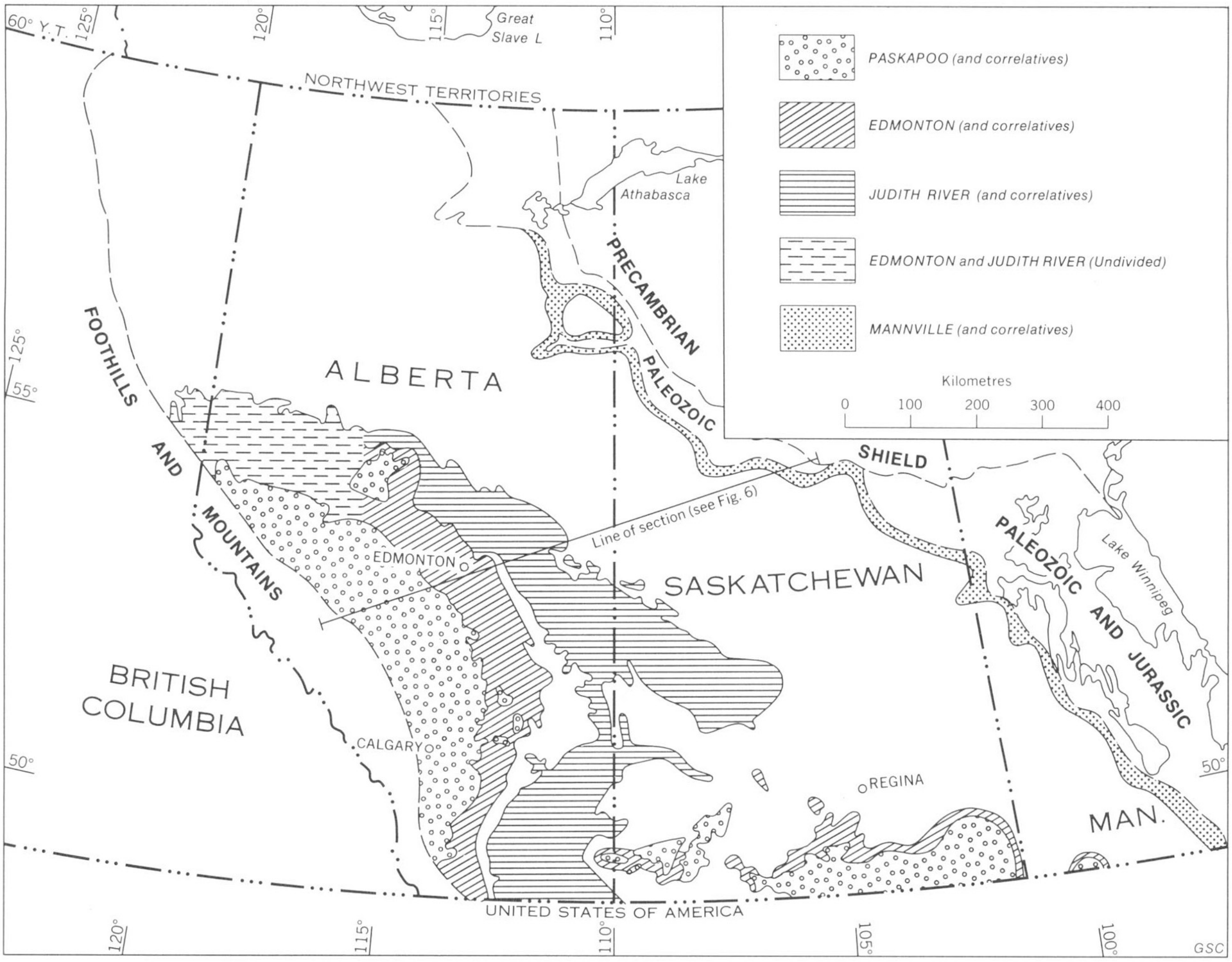

Figure 5. *Generalized bedrock surface geology, Canadian Plains (after GSC Map 1250A, Geological Map of Canada, 1:5 000 000).*

Resources (Figure 7). Four levels of confidence (decreasing assurance of existence), based on distance from boreholes have been used, defined as follows:

"measured" - 400 m or less from a borehole

"indicated" - more than 400 m but within 800 m of a borehole

"inferred A" - more than 800 m but within 2400 m of a borehole

"inferred B" - more than 2400 m from a borehole.

Overriding these levels of confidence are the reliability index categories or probabilities that any given seam is actually present in a given borehole.

Table 3

Statistical summary, all seams (values in m) minimum thickness 0.3 m

PROVINCE	RELIABILITY INDEX CATEGORY	STRAT. UNIT	AVG. THICKNESS	MAX. THICKNESS	AVG. DEPTH	MAX. DEPTH	NUMBER OF SEAM INTERSECTIONS
Manitoba		No coal encountered					
Saskatchewan	1-2	Mannville	1.0	3.4	781	1272	110
		Judith River	1.0	2.4	256	449	19
	3-5	Mannville	1.0	3.0	855	1310	84
		Judith River	1.2	3.7	343	678	74
Alberta	1-2	Mannville	1.5	12.2	1385	3075	3022
		Judith River	1.0	5.2	313	1476	373
		Edmonton	1.4	11.0	422	1709	1141
		Paskapoo	1.4	4.9	500	779	46
	3-5	Mannville	1.2	7.6	1183	2816	578
		Judith River	1.0	6.7	351	1753	566
		Edmonton	1.3	6.7	453	1678	792
		Paskapoo	1.9	6.1	452	658	75
British Columbia	1-2	Mannville	0.8	2.7	1118	1535	131
	3-5	Mannville	0.8	2.4	1067	1426	57
						Total	7068

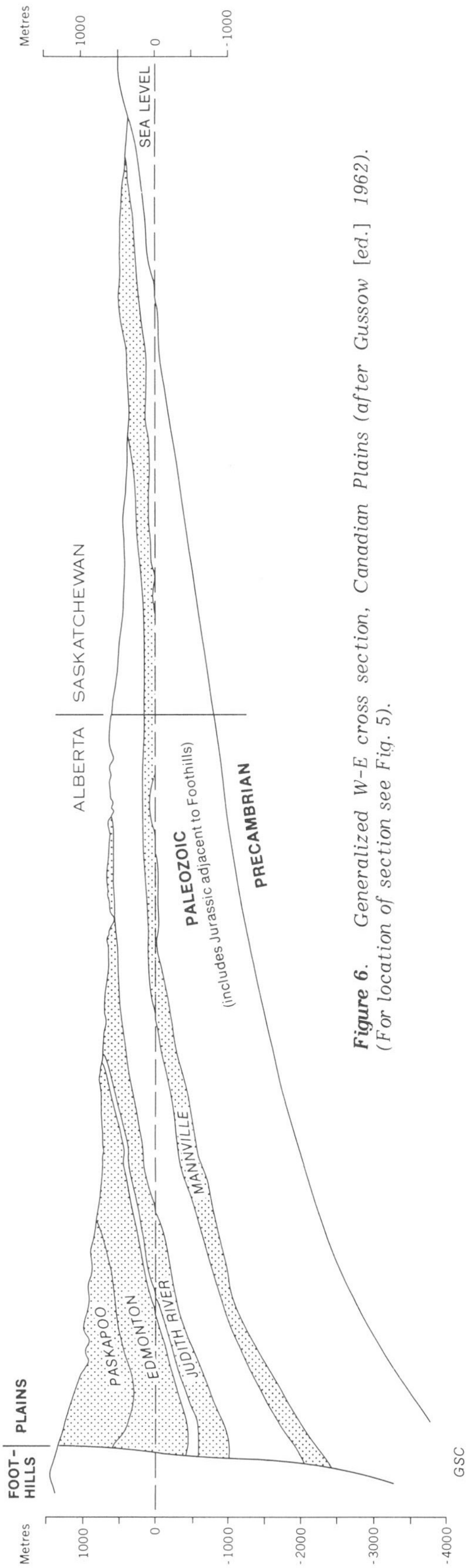

Figure 6. Generalized W-E cross section, Canadian Plains (after Gussow [ed.] 1962). (For location of section see Fig. 5).

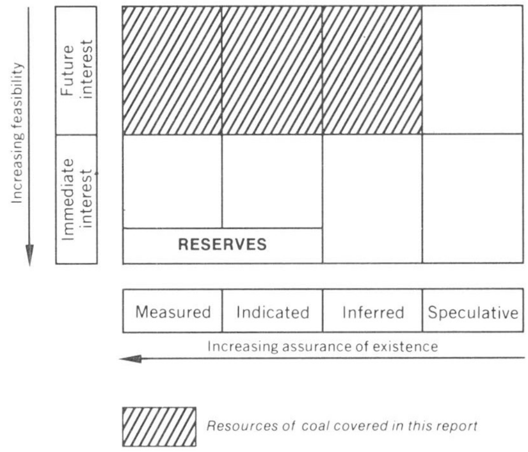

Figure 7. Coal resource classification scheme (after Bielenstein et al., 1979).

Calculations

Data from 7068 individual seam intersections were used in this study. Table 3 summarizes the average and maximum seam thicknesses and depths by stratigraphic unit, reliability index category and province for all 7068 seam intersections greater than 0.3 m thick. Table 4 presents the same information for the 1194 seam intersections which were 2 m thick or thicker.

No attempt was made to correlate seams and calculate resources on a seam-by-seam basis, though locally some seams are sufficiently thick and persistent to make correlation possible, even between holes as widely spaced as they were in this study. The total thickness of all coal seams selected in a borehole by depth range or stratigraphic unit was simply cumulated and the resulting number treated as if it were a continuous variable from borehole to borehole. It is the authors' view that this procedure is sufficiently accurate for reconnaissance studies provided a relatively large number of boreholes (more than about 50) is used.

The methods used in mapping total coal thickness and calculating resources by level of confidence for each depth interval and stratigraphic unit are those which were described by Irvine et al. (1978). Because the average borehole spacing is somewhat greater than 10 km, a primary grid spacing of 10 km was chosen for mapping and a 2.5 km grid was used for categorization of quantities as "measured", "indicated" and "inferred".

Based on surface and near-surface information (Steiner et al., 1972) the coals dealt with in this study probably range from subbituminous to high volatile bituminous in the A.S.T.M. classification. Calculation of tonnages was made using an average specific gravity of 1.30, a value which is considered to be broadly representative of low-ash coals of this rank range in the Plains, and which in turn will produce conservative quantity estimates.

Seams with reliability index categories of 1 and 2 were first selected from the data base, then grouped into those which were 2 m thick or thicker, and those which were less than 2 m thick. Each of these groups was then split into subgroups, first according to depth (<300 m, 301 m-500 m, 501 m-1000 m, >1000 m) and second according to stratigraphic unit (Mannville, Judith River, Edmonton, Paskapoo) and the total thickness of coal in each subgroup cumulated in each borehole. These cumulative thickness values were used to estimate tonnages and map thicknesses using the gridding procedure described by Irvine et al. (1978), modified as described above. Each of the five UTM Zones (10 to 14 inclusive) was gridded separately; if the selection procedures reduced the number of boreholes in a zone to less than 10, no grid was generated, no quantities were estimated and no map was produced.

All remaining seams having reliability index categories of 3, 4 and 5 were combined and handled in the same way.

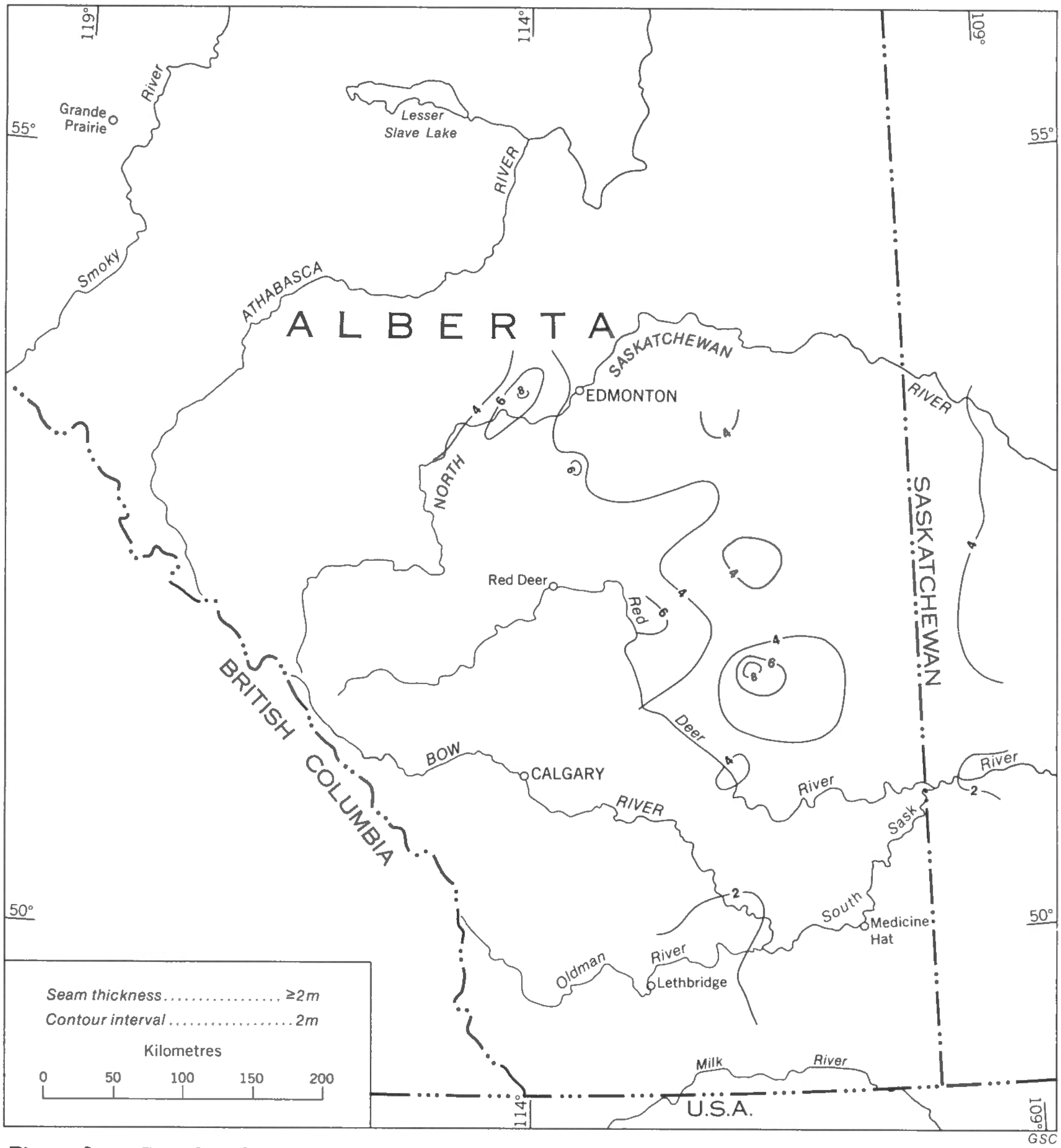

Figure 8. *Cumulated coal thickness. Depth less than 300 m. Reliability Index Categories 1 and 2.*

Table 4

Statistical summary, seams 2 m thick or thicker (values in m)

PROVINCE	RELIABILITY INDEX CATEGORY	STRAT. UNIT	AVG. THICKNESS	MAX. THICKNESS	AVG. DEPTH	MAX. DEPTH	NUMBER OF SEAM INTERSECTIONS
Manitoba		No coal encountered					
Saskatchewan	1-2	Mannville	2.4	3.4	763	847	11
		Judith River	2.2	2.4	222	244	2
	3-5	Mannville	2.3	3.0	815	1002	8
		Judith River	2.7	3.7	228	387	11
Alberta	1-2	Mannville	3.3	12.2	1528	2940	644
		Judith River	2.6	5.2	325	1433	23
		Edmonton	3.2	11.0	402	1641	200
		Paskapoo	3.0	4.9	463	736	11
	3-5	Mannville	3.0	7.6	1244	2612	74
		Judith River	2.9	6.7	332	1213	42
		Edmonton	2.9	6.7	424	1089	123
		Paskapoo	2.9	6.1	454	658	37
British Columbia	1-2	Mannville	2.2	2.7	1148	1282	4
	3-5	Mannville	2.2	2.4	1172	1426	4
						Total	1194

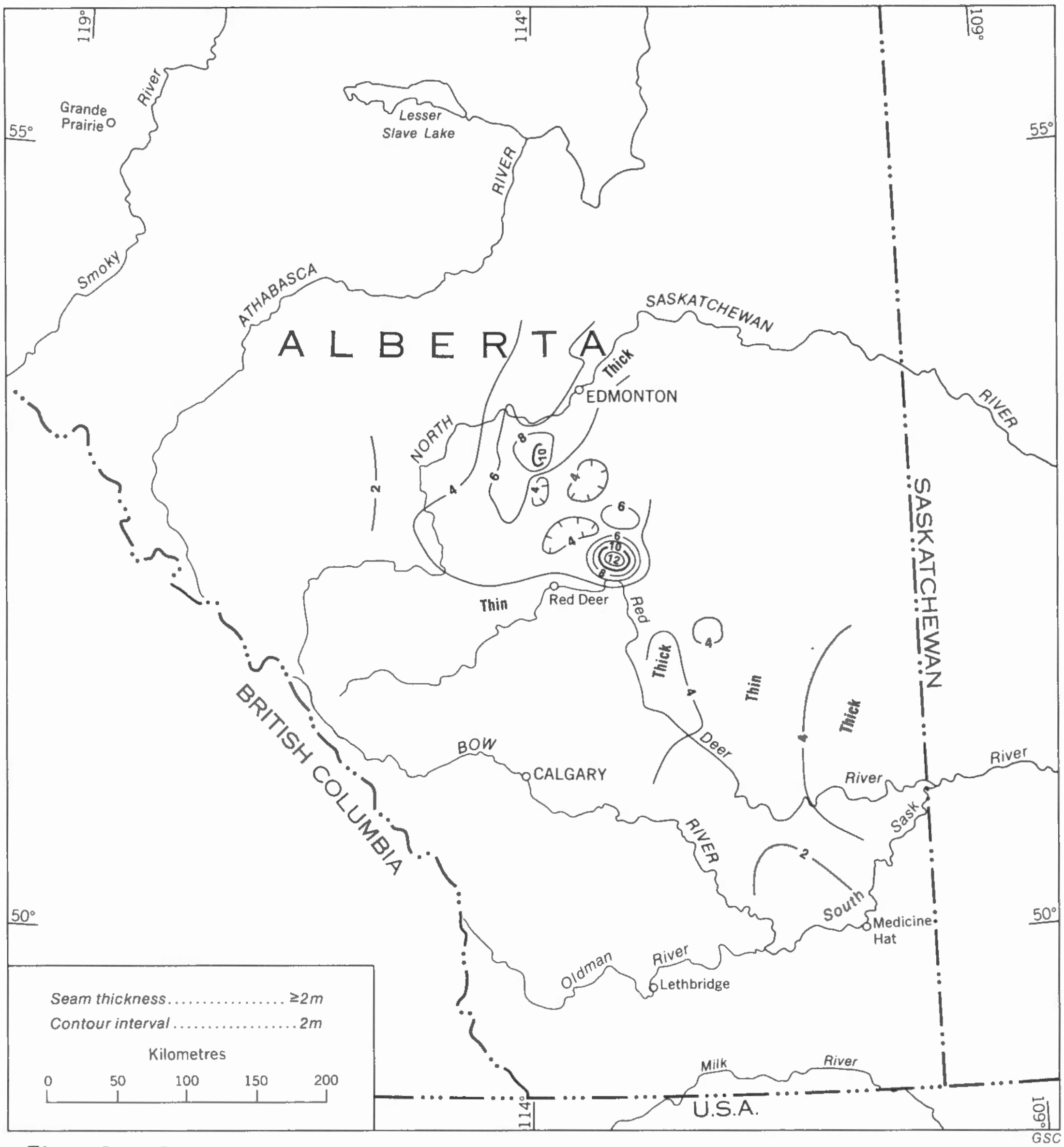

Figure 9. *Cumulated coal thickness. Depth 300 to 500 m. Reliability Index Categories 1 and 2.*

Table 5

Saskatchewan (Reliability Index Categories 1 and 2)
Estimated deep coal resource quantities in megatonnes

THICKNESS	LEVEL OF CONFIDENCE	DEPTH (in metres)				TOTAL
		< 300*	301-500	501-1000	> 1000	
> =2 m	Measured			108		108
	Indicated			166		166
	Inferred "A"	None	None	2 040	None	2 040
	Inferred "B"			13 800		13 800
< 2m	Measured		224	313		537
	Indicated		426	1 070		1 490
	Inferred "A"	None	4 850	9 500	None	14 300
	Inferred "B"		34 700	85 000		120 000

*In this study only; see for example Irvine et al., 1978; Bielenstein et al., 1979, for coal resources within this depth range.

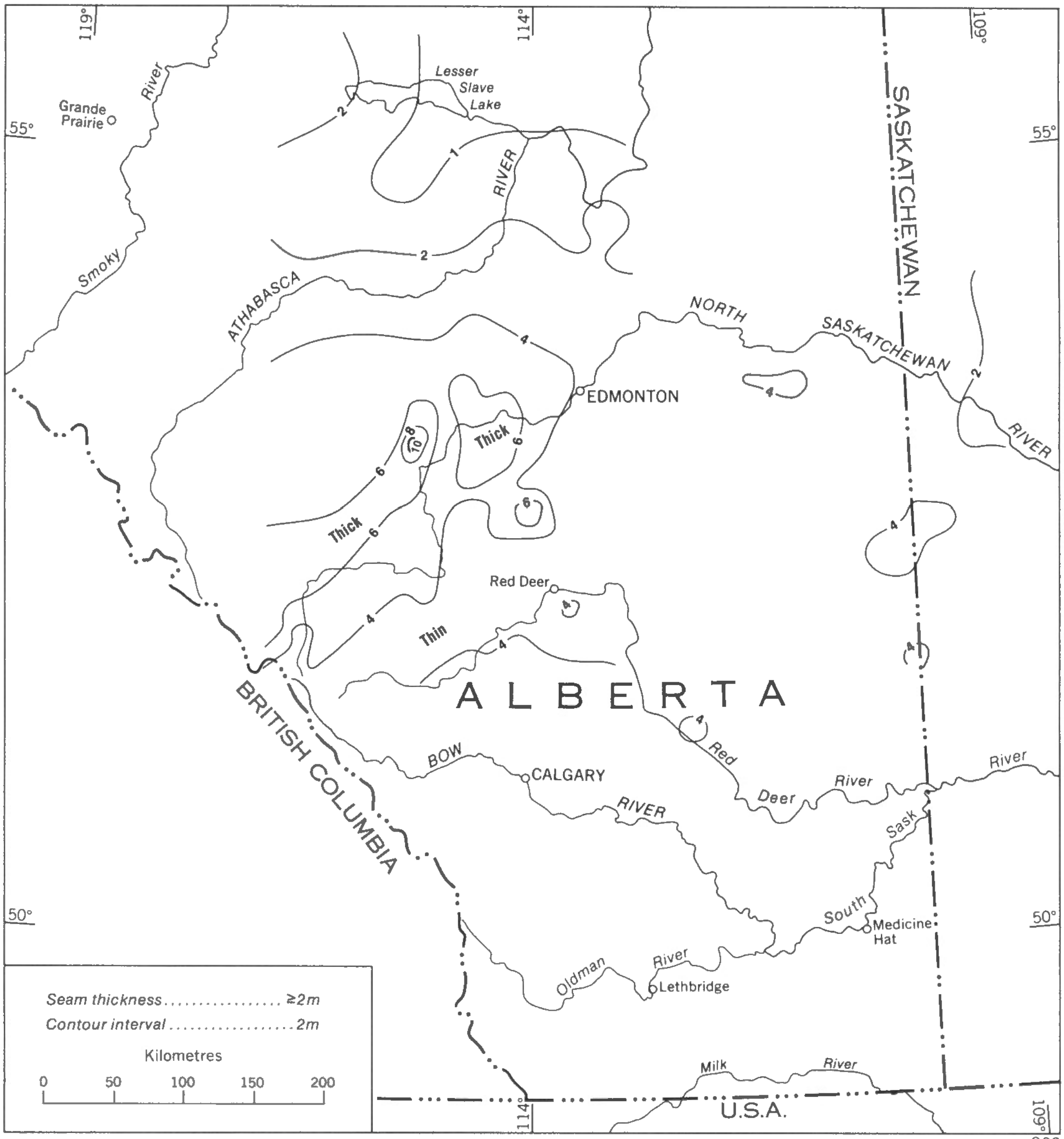

Figure 10. *Cumulated coal thickness. Depth 500 to 1000 m. Reliability Index Categories 1 and 2.*

Table 6

Saskatchewan (Reliability Index Categories 3 to 5)
Estimated deep coal resource quantities in megatonnes

THICKNESS	LEVEL OF CONFIDENCE	DEPTH (in metres)				TOTAL
		< 300*	301-500	501-1000	> 1000	
> =2 m	Measured Indicated Inferred "A" Inferred "B"	None	None	None	None	None
< 2m	Measured		68	271	100	439
	Indicated		220	771	210	1 200
	Inferred "A"	None	2 360	7 770	2 490	12 600
	Inferred "B"		16 300	57 300	18 100	91 700

*In this study only; see for example Irvine et al., 1978; Bielenstein et al., 1979, for coal resources within this depth range.

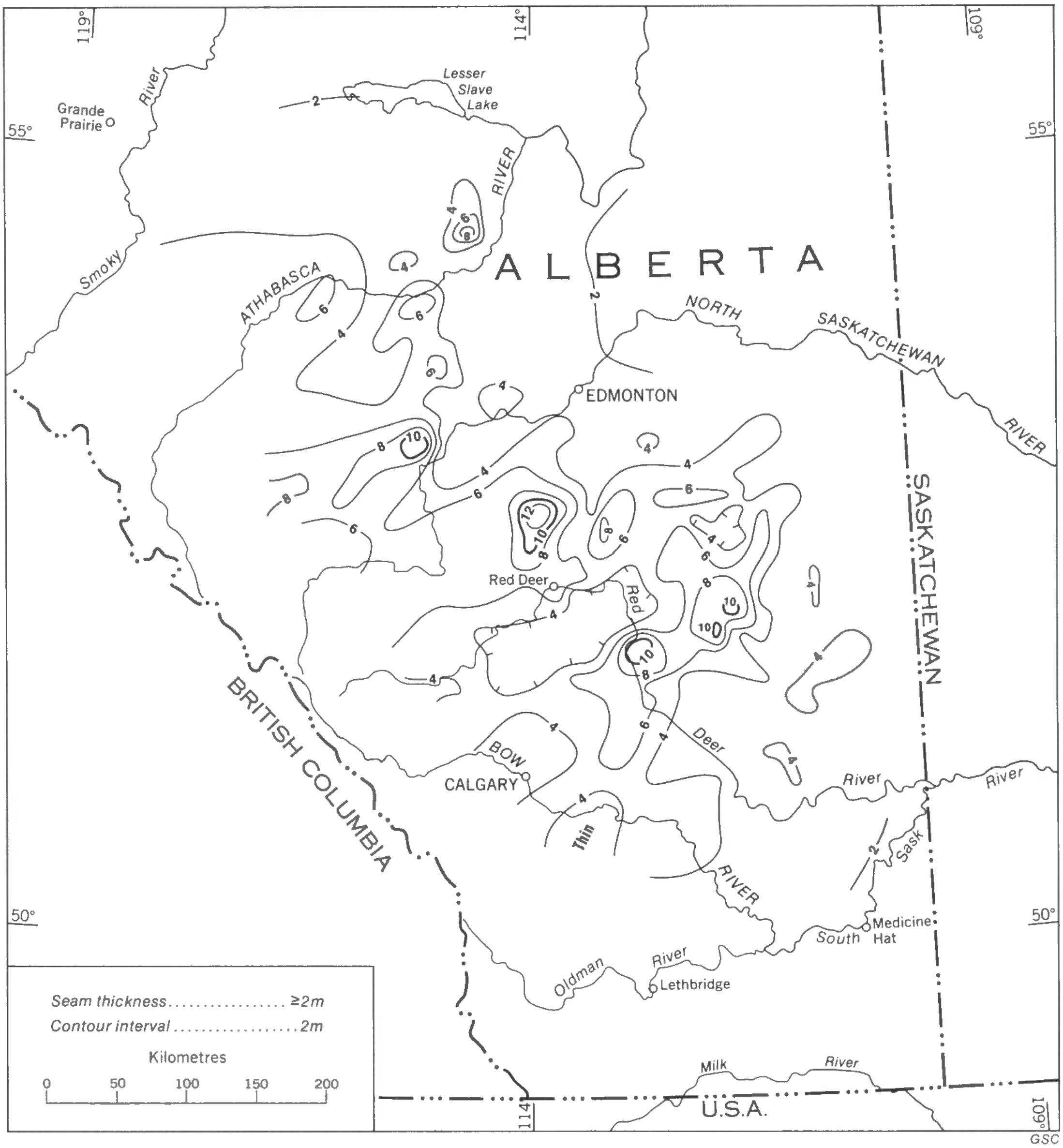

Figure 11. *Cumulated coal thickness. Depth greater than 1000 m. Reliability Index Categories 1 and 2.*

Table 7

Alberta (Reliability Index Categories 1 and 2)
Estimated deep coal resource quantities in megatonnes

THICKNESS	LEVEL OF CONFIDENCE	DEPTH (in metres)				TOTAL
		< 300*	301-500*	501-1000	> 1000	
>=2 m	Measured	2 410	1 220	2 370	2 680	8 680
	Indicated	6 430	3 930	7 330	7 840	25 500
	Inferred "A"	71 000	50 200	81 600	90 500	293 000
	Inferred "B"	403 000	283 000	502 000	541 000	1 730 000
< 2m	Measured	1 430	1 290	1 520	1 860	6 100
	Indicated	4 460	4 250	4 940	5 400	19 000
	Inferred "A"	46 100	45 400	55 100	61 600	208 000
	Inferred "B"	263 000	260 000	347 000	382 000	1 250 000

*In this study only; see for example Alberta Energy Resources Conservation Board, 1979; Bielenstein et al., 1979, for coal resources within these depth ranges.

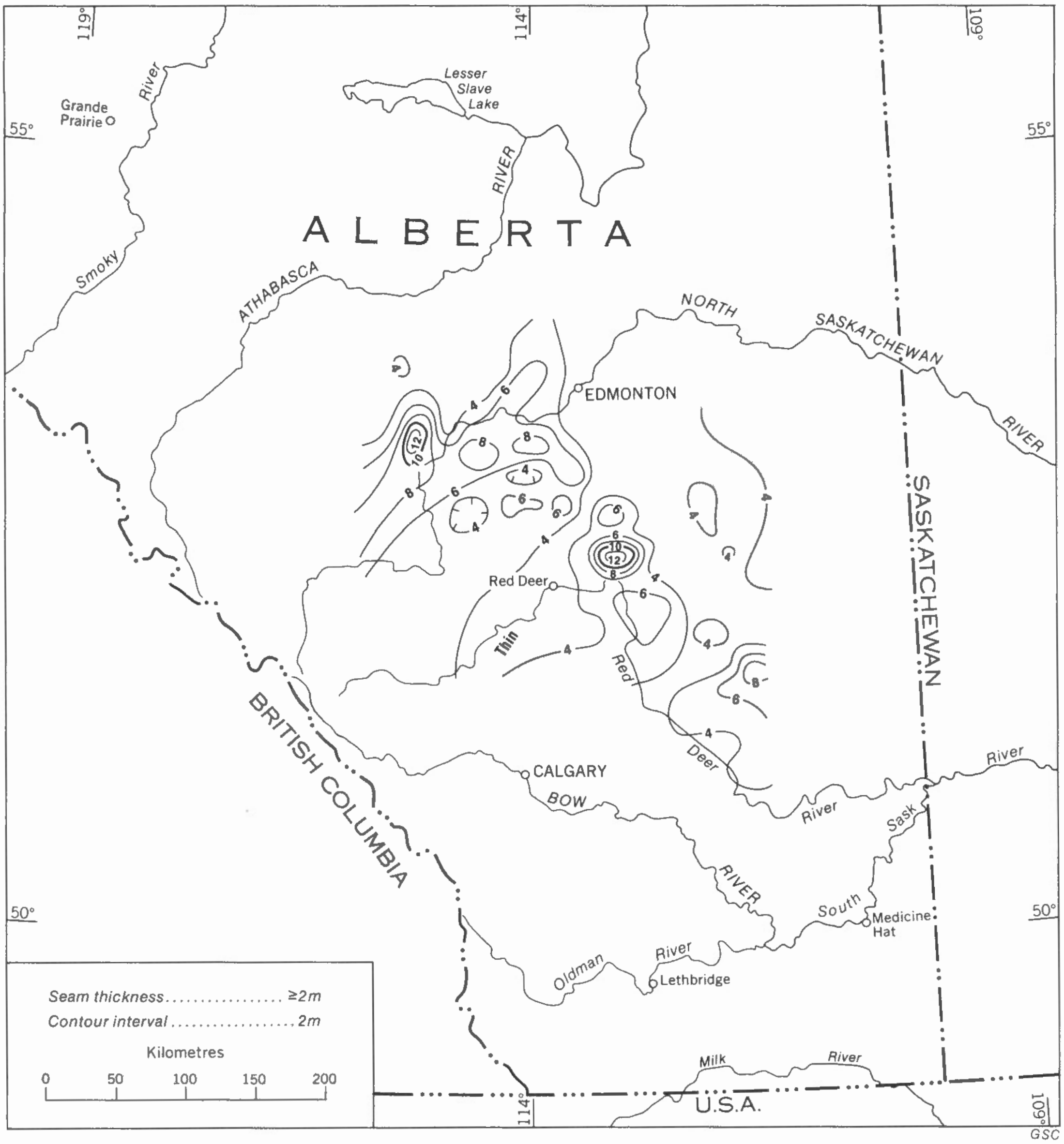

Figure 12. *Cumulated coal thickness. Edmonton Group. Reliability Index Categories 1 and 2.*

Table 8

Alberta (Reliability Index Categories 3 to 5)
Estimated deep coal resource quantities in megatonnes

THICKNESS	LEVEL OF CONFIDENCE	DEPTH (in metres)				TOTAL
		< 300*	301-500*	501-1000	> 1000	
>=2 m	Measured	2 220	2 270	3 450	2 040	9 970
	Indicated	5 780	6 750	10 300	7 090	29 900
	Inferred "A"	59 000	76 100	114 000	81 300	330 000
	Inferred "B"	340 000	440 000	675 000	487 000	1 940 000
< 2m	Measured	1 080	1 060	1 210	1 290	4 640
	Indicated	3 390	3 370	3 960	3 900	14 600
	Inferred "A"	36 100	38 200	43 600	42 800	161 000
	Inferred "B"	211 000	230 000	276 000	265 000	982 000

*In this study only; see for example Alberta Energy Resources Conservation Board, 1979; Bielenstein et al., 1979, for coal resources within these depth ranges.

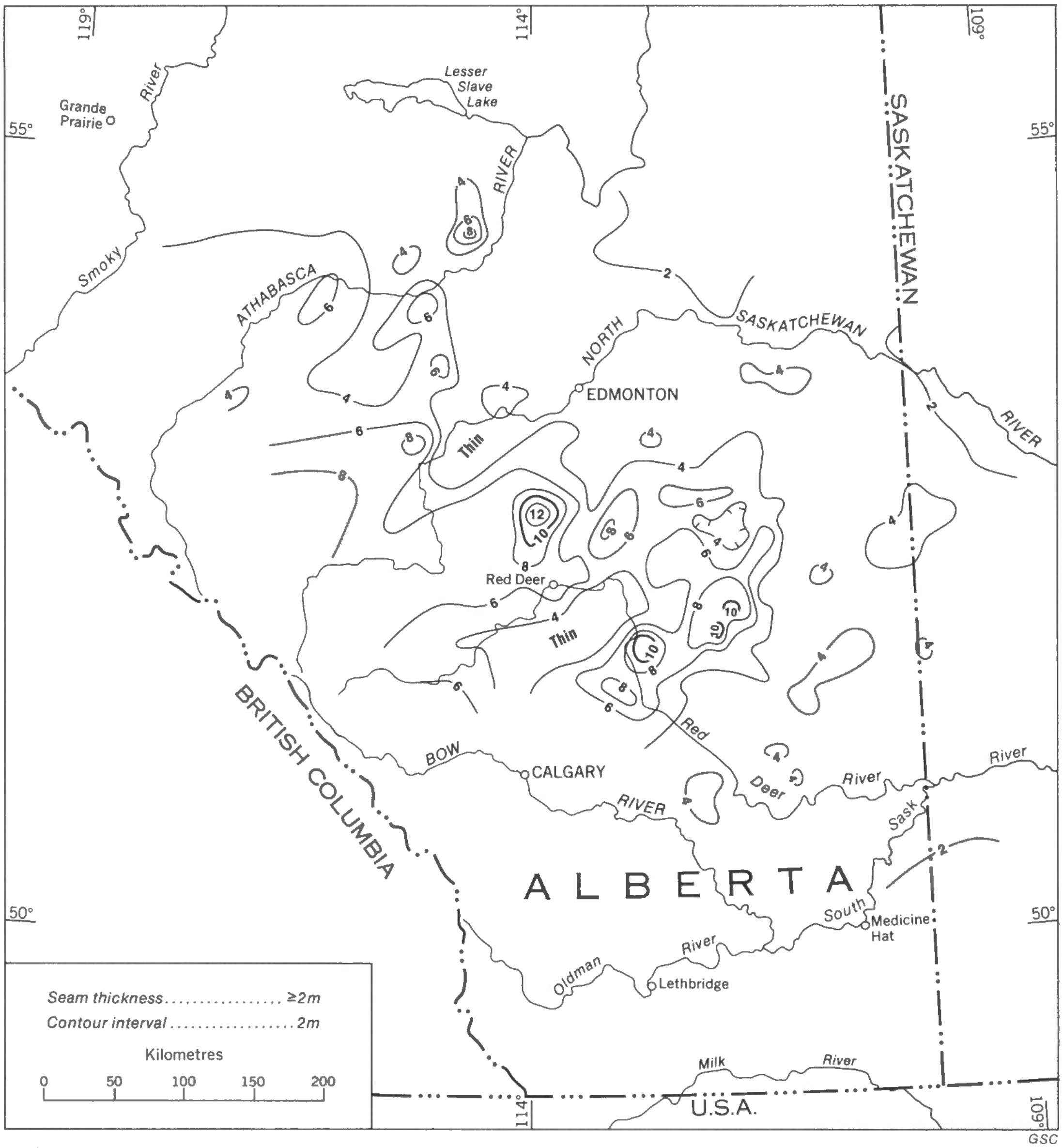

Figure 13. *Cumulated coal thickness. Mannville Group. Reliability Index Categories 1 and 2.*

Table 9

British Columbia (Reliability Index Categories 1 and 2)
Estimated deep coal resource quantities in megatonnes

THICKNESS	LEVEL OF CONFIDENCE	DEPTH (in metres) < 300*	301-500*	501-1000	> 1000	TOTAL
>=2 m	Measured					
	Indicated					
	Inferred "A"	None	None	None	None	None
	Inferred "B"					
< 2m	Measured			36	48	84
	Indicated			64	530	594
	Inferred "A"	None	None	1 150	3 660	4 810
	Inferred "B"			7 150	23 200	30 400

*In this study only; see for example Bielenstein et al., 1979, for coal resources within these depth ranges.

Table 10

British Columbia (Reliability Index Categories 3 to 5)
Estimated deep coal resource quantities in megatonnes

THICKNESS	LEVEL OF CONFIDENCE	DEPTH (in metres) < 300*	301-500*	501-1000	> 1000	TOTAL
> =2 m	Measured Indicated Inferred "A" Inferred "B"	None	None	None	None	None
< 2m	Measured			31	56	87
	Indicated			57	250	307
	Inferred "A"	None	None	408	2 140	2 550
	Inferred "B"			3 160	13 300	16 500

*In this study only; see for example Bielenstein et al., 1979, for coal resources within these depth ranges.

Table 11

Western Interior Plains
(Reliability Index Categories 1 and 2)
Estimated deep coal resource quantities in megatonnes

THICKNESS	LEVEL OF CONFIDENCE	SASK.	ALTA.	B.C.	TOTAL
> =2 m	Measured	108	8 680		8 790
	Indicated	166	25 500	None	25 700
	Inferred "A"	2 040	293 000		295 000
	Inferred "B"	13 800	1 730 000		1 740 000
< 2 m	Measured	537	6 100	84	6 720
	Indicated	1 490	19 000	594	21 100
	Inferred "A"	14 300	208 000	4 810	227 000
	Inferred "B"	120 000	1 250 000	30 400	1 400 000

Table 12

Western Interior Plains
(Reliability Index Categories 3 to 5)
Estimated deep coal resource quantities in megatonnes

THICKNESS	LEVEL OF CONFIDENCE	SASK.	ALTA.	B.C.	TOTAL
> =2 m	Measured		9 970		9 970
	Indicated	None	29 900	None	29 900
	Inferred "A"		330 000		330 000
	Inferred "B"		1 940 000		1 940 000
< 2 m	Measured	439	4 640	87	5 170
	Indicated	1 200	14 600	307	16 100
	Inferred "A"	12 600	161 000	2 550	176 000
	Inferred "B"	91 700	982 000	16 500	1 090 000

Results

Estimated coal resource quantities are tabulated by depth range, level of confidence, thickness and reliability index category for Saskatchewan (Tables 5 and 6), Alberta (Tables 7 and 8) and British Columbia (Tables 9 and 10), and summarized for the western Canadian Interior Plains in Tables 11 and 12. All values have been rounded to three significant figures after summation. It must be noted that the estimated quantities given for the shallower depth ranges (less than 500 m) marked with asterisks (*) in Tables 5 to 10 refer to quantities calculated from petroleum borehole data used in this study only, and these data are incomplete because of the presence of surface casing in the boreholes. These values represent minimum values only and other authors (Alberta Energy Resources Conservation Board, 1979; Bielenstein et al., 1979 and Irvine et al., 1978) must be consulted for more complete resource estimates within these depth intervals.

Cumulated thickness of seams with reliability index categories of 1 and 2 were mapped by depth range (Figures 8 to 11) and stratigraphic interval (Figures 12 and 13).

Analysis of stratigraphic data for seam intersections with reliability index categories of 1 and 2 indicates that for the thicker seams (>2 m) in Alberta, half the coal is in the Mannville Group with the remainder evenly distributed between the Judith River Formation and Edmonton Group, whereas in Saskatchewan all the coal is in the Mannville Group. For the thinner seams (<2 m), all the coal in British Columbia occurs in the Mannville Group; in Alberta half occurs in the Mannville with the Judith River Formation accounting for about 20 per cent and the remainder in the Edmonton Group; in Saskatchewan more than 90 per cent of the coal occurs in the Mannville Group with the remainder in the Judith River Formation. Overall, more than 90 per cent of the coal resources identified in this study occur in Alberta with most of the remainder in Saskatchewan and only a small quantity in northeastern British Columbia.

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