Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

Coal Resources and Reserves of Canada

Report ER 79-9

Coal Resources and Reserves of Canada
A Very Abbreviated Metric Guide

All measurements presented in this report are given in the International System of Units (SI) as approved for official use by the Canadian Standards Association and Metric Commission Canada and adopted by The Mining Association of Canada and the Coal Association of Canada for uniform use in mining, milling, smelting and refining operations in Canada. The latter two organizations have published the "Metric Practice Guide for the Canadian Mining and Metallurgical Industries" from which the prefixes, terminology and conversion factors listed below were taken.

Conversion Factors and Terminology

Multiply this		*by this*	*to obtain*	
foot		0.304 8	metre	m
metre	m	3.280 84	feet	
mile		1.609 344	kilometre	km
kilometre	km	0.621 371	mile	
long ton		1.016 046 908 8	metric ton	t
metric ton	t	0.984 206 5	long ton	
metric ton	t	1.102 311	short ton	
short ton		0.907 184 74	metric ton	t
British thermal unit (Int)	Btu	1 055.06	joule	J
Btu per pound		0.002 326	megajoule per kilogram	MJ/kg
joule	J	0.000 947 8	Btu (Int)	
megajoule per kilogram	MJ/kg	429.923	Btu per pound	

SI Prefixes

Multiplying Factor	*Prefix*	*Symbol*
1 000 000 000 000 000 000 = 10^{18}	exa	E
1 000 000 000 000 000 = 10^{15}	peta	P
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	hecto	h
10 = 10^{1}	deca	da

Coal Resources and Reserves of Canada

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Preface

Long-term projections indicate that coal demand will increase dramatically within the next 20 years placing pressure on finding, developing and financing new supplies. This report on the location, quantity and quality of Canada's coal resources and reserves is intended to provide basic information to a diverse audience including producers, consumers, transporters, investors, energy planners, governments and the general public. An accurate assessment of coal resources and reserves is an essential step towards using coal effectively to help supply Canada's future energy requirements and those of offshore markets.

Beginning in the late 1960s the increase in coal exploration by both the private and public sector has generated considerable new information on Canada's coal resources and reserves. Some of the new resource information was published in this report's predecessor, the 1976 Assessment of Canada's Coal Resources and Reserves which was designed to give the reader a better understanding and appreciation of the confidence of the estimates. This report makes use of information available to the authors in early 1979 for the quantity and quality of resources, and in early 1978 for the quantity and quality of reserves. In this report the International System of Units (SI) is used throughout.

The quantities of MEASURED RESOURCES of immediate interest are estimated at 16.8 gigatons of bituminous coal, 30.0 gigatons of subbituminous coal and 3.6 gigatons of lignitic coal. The quality aspects of the resources are also discussed in the report.

The section on reserves includes estimates of both MINEABLE COAL - Level 1 and RECOVERABLE COAL - Level 2. Current estimates of MINEABLE COAL - Level 1 are estimated at 7.3 gigatons of subbituminous coal and 5.6 gigatons of bituminous coal and at least 3.2 gigatons of lignitic coal. Reserves of RECOVERABLE COAL - Level 2 are estimated at 2.1 gigatons of lignitic coal, 2.2 of subbituminous coal and 1.6 gigatons of bituminous coal. Because of incomplete returns from several companies and utilities, the estimate of current reserves of recoverable coal is considered to be conservative.

Préface

Les prévisions à long terme montrent que la demande de charbon augmentera sensiblement au cours des 20 prochaines années, rendant ainsi nécessaire la découverte, la mise en valeur et le financement de nouveaux approvisionnements. Le présent rapport, qui porte sur l'emplacement, la quantité et la qualité des ressources et des réserves de charbon au Canada, est une source de renseignements élémentaires à l'intention d'un public varié regroupant producteurs, consommateurs, transporteurs, investisseurs, planificateurs en matière d'énergie, gouvernements et le grand public. L'évaluation précise des ressources et des réserves représente une étape essentielle en vue de l'utilisation efficace du charbon pour aider à répondre aux besoins énergétiques futurs du Canada et des pays étrangers.

Depuis la fin des années 60, l'accélération des travaux de prospection du charbon dans les secteurs privé et public s'est traduite par l'accumulation de nombreux renseignements nouveaux sur les ressources et les réserves de charbon. Certains de ces renseignements étaient publiés dans le rapport précédent, l'Évaluation en 1976 des ressources et des réserves en charbon au Canada, qui avait pour but d'amener le lecteur à mieux comprendre et apprécier la justesse des estimations faites. Le présent rapport comprend les données quantitatives et qualitatives dont disposaient les auteurs au début de 1979 sur les ressources et au début de 1978 sur les réserves. Les auteurs ont adopté le Système international d'unités.

Les quantités de ressources mesurées d'intérêt immédiat sont évaluées à 16,8 Gt de charbon bitumineux, à 30,0 Gt de charbon subbitumineux et à 3,6 Gt de lignite. Les ressources sont également considérées sous leur aspect qualitatif.

Le chapitre sur les réserves comprend les estimations relatives au CHARBON EXPLOITABLE (niveau 1) et au CHARBON RÉCUPÉRABLE (niveau 2). En ce qui concerne le CHARBON EXPLOITABLE (niveau 1), les réserves s'élèveraient à 7,3 Gt de charbon subbitumineux, à 5,6 Gt de charbon bitumineux et à au moins 3,2 Gt de lignite. Quant au CHARBON RÉCUPÉRABLE (niveau 2), il y aurait 2,1 Gt de lignite, 2,2 Gt de charbon subbitumineux et 1,6 Gt de charbon bitumineux. Puisque plusieurs sociétés et services publics n'ont remis que des données incomplètes, les estimations des réserves actuelles de charbon récupérable sont considérées comme étant modérées.

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Acknowledgement

The authors are grateful to the representatives of the British Columbia Ministry of Energy, Mines and Petroleum Resources, Alberta Energy Resources Conservation Board, Saskatchewan Department of Mineral Resources, New Brunswick Department of Natural Resources, Nova Scotia Department of Mines and The Coal Association of Canada for assistance in providing information on coal resources and reserves in Canada. In addition the Department of Energy, Mines and Resources wishes to acknowledge the excellent response and cooperation of the coal mining and exploration companies in Canada with respect to the annual reserves questionnaire.

Introduction

Background

This second assessment of resources and reserves is part of a series that began in 1976 intended to provide an update on Canada's coal resources and reserves in terms of quantity and quality. Enough changes and additional new information have been produced in the interim to warrant publication of the 1978 report. It is intended that the series will be continued when significant new information becomes available.

Shortly after the publication of the 1976 report (EP 77-5), the authors held discussions with provincial and industry representatives to obtain recommendations for future resource and reserve assessments. The authors have incorporated many of the suggestions that were put forward with the result that the present assessment reflects some changes in parameters, terminology, reserve categories and reporting of coal quantities and qualities. In addition SI units have been used throughout the report. An abbreviated conversion guide to SI units is located inside the front cover for the convenience of the reader.

Department's Current Objectives

The Department of Energy, Mines and Resources is continuing efforts to reduce national dependence on imported oil by development of indigenous energy resources such as coal to substitute for those oil supplies wherever feasible. The Department in collaboration with the provinces and industry is conducting a continuing appraisal of Canada's coal resources and reserves as part of the National Coal Inventory Program.

Coal Assessment Group

In order to improve understanding of Canada's coal reserves and resources, the Department of Energy, Mines and Resources established the Coal Assessment Group based on the coal expertise within the Department. This Group has coordinated and prepared for publication the 1976 Assessment and this report of Canada's Coal Resources and Reserves.

Coal Industry in Canada

Mines and Production

In 1978 Canadian production of all types of coal rose to 30.2 megatons valued at $776 million, an increase over the 28.7 megatons produced in 1977 (Table 1). Bituminous coal production (from Nova Scotia, New Brunswick, Alberta, British Columbia and the Yukon Territories) reached 17.1 megatons in 1978 compared with 15.3 megatons in 1977. Subbituminous production, all of which came from Alberta, totalled 8.2 megatons compared with 7.9 megatons in 1977. Lignitic production was 5.0 megatons in 1978 down from 5.5 megatons in 1977. About 16.6 megatons or 55 per cent of the total production was coal of coking quality with the remainder of thermal coal quality. In 1978 an estimated 85 per cent of the total production was mined by surface methods.

In 1978, 40 mines were in production, and 16 produced more than 0.5 megaton each. The coal industry in Canada ranges from large mines producing over 5 megatons annually to small independent mines producing less than 0.1 megaton annually. In western Canada private companies produce all coal with the exception of a provincial utility in Saskatchewan whereas a federal crown corporation predominates in Nova Scotia and a provincial crown corporation in New Brunswick. Figure 1 shows the general areas of the principal operating mines for 1978.

Consumption

Coal consumption in Canada totalled 31.7 megatons in 1978, of which 22.9 megatons were used to generate electric power and 6.9 megatons were used to produce coke for the steel industry. The remainder (1.9 megatons) was consumed by industrial and commercial users throughout Canada. Table 2 illustrates the 1976-78 coal supply and demand balance by major consuming sectors.

In 1978, coal exports totalled 14.0 megatons of which 93 per cent comprised coking coal shipped principally to Japan, Korea and Brazil. The remainder, including coking and bituminous thermal coal, was exported to 13 other countries.

Exploration and New Developments 1977-78

Coal exploration consisting of field mapping, geophysical surveys, trenching, driving of adits and drilling was carried out by both private industry and government in many parts of Canada.

In the Yukon and Northwest Territories new interest in the resource potential has been shown by coal exploration companies. Conditions are far from ideal for exploration in the north nevertheless reports of coals of

TABLE 1
1978 Value of Coal Production FOB Mines

	Surface mining		Underground mining		Total	
Area	kilotons	$ 000	kilotons	$ 000	kilotons	$ 000
MARITIMES						
Thermal	362	11 643	1 159	39 323	1 521	50 966
Coking	-	-	1 144	75 398	1 444	75 398
Total		11 643		114 721		126 364
WESTERN CANADA						
Thermal	15 140	94 727	36	312	15 176	95 039
Coking	10 550	470 785	1 786	83 936	12 336	554 721
Total		565 512		84 248		649 760
CANADA						
Thermal	15 502	106 370	1 195	39 635	16 697	146 005
Coking	10 550	470 785	2 930	159 334	13 480	630 119
Total		577 155		198 969		776 124

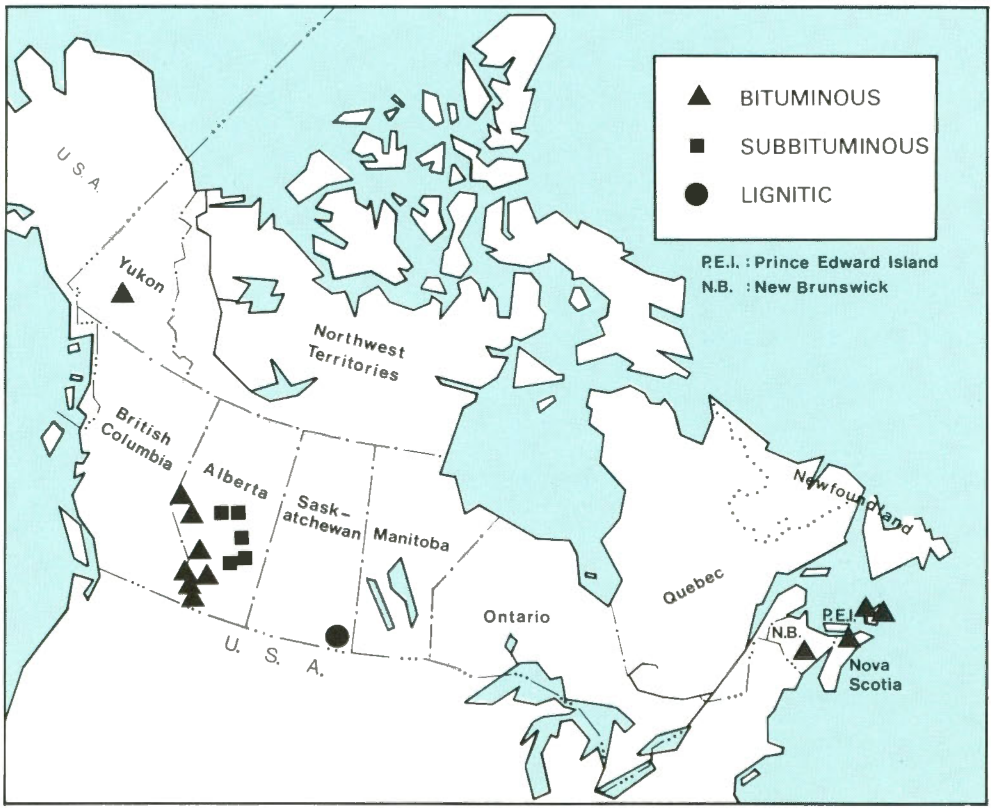

Figure 1. Areas of operating coal mines (1978).

TABLE 2
1976-78 Coal Supply and Demand
(kilotons)

	1976	1977	1978
SUPPLY			
Marketed coal	25 470	28 681	30 477
Imported coal	14 619	15 435	14 119
Total supply	40 089	44 116	44 596
DEMAND			
Thermal electric	19 041	22 437	22 915
Metallurgical	7 388	6 663	6 909
General industry	1 570	1 604	1 688
Space heating	216	185	226
Total domestic consumption	28 215	30 889	31 738
Exports	11 855	12 384	14 000
Total demand	40 070	43 273	45 738
Inventory changes	+ 19	+ 843	- 1 142

good quality in mineable thicknesses along with the possible development of new markets have prompted some limited geologic mapping trenching and drilling.

In British Columbia exploration work was conducted in four main areas of the province, Vancouver Island, south central, southeastern and northeastern. On Vancouver Island, thermal coal was the prime objective whereas in the northeastern part of the province detailed feasibility studies of production options for coking coal were in progress. In the southeastern part of the province, work continued on a number of sites that have potential for coking coal production. These include possible expansion of existing mining operations. In the south central area, the provincial utility continued to evaluate the large lignite deposit at Hat Creek.

In Alberta the prospects of new markets for bituminous thermal coal have encouraged exploration activity in the Foothills Region. Exploration for coking coal in the province slowed considerably because of the depressed world markets. The shallow deposits of subbituminous coal in the Plains Region offer significant potential for mine site power generation, heavy oil and oil sands processing and coal conversion.

In Saskatchewan, a geological report and resource estimate based on the joint federal-provincial coal resource exploration program which commenced in 1972 were published in 1978 (Irvine, J.A. et al., 1978). A similar report on coal quality will be published in 1979. About 60 per cent of the electrical energy in the province is produced from coal. Work is proceeding to develop surface mineable lignitic deposits that will supply a new mine-mouth power plant.

Ontario's only significant coalfield, Onakawana, has been explored extensively and studies were continued with the objective of establishing a lignite-fired mine-mouth power plant.

In New Brunswick and Nova Scotia, government agencies drilled and mapped the more favourable coal basins that occur in these provinces. Some private companies have been involved in feasibility studies of individual coal properties. At Sydney, Nova Scotia, on Cape Breton Island offshore coal exploration drilling was conducted from an oil exploration ship during the 1977 and 1978 summer seasons. The results of this work are now being studied.

Rank and Quality of Coal

Coal is a complex material made up mainly of consolidated organic residues from vegetation that grew, died and partially decomposed in peat basins. However most coal that is mined includes not only mineral matter from the original vegetation but also extraneous mineral matter carried into the swampy basins by wind and water. This mineral matter became intermixed and inter-bedded with the carbonaceous material during the periods of deposition.

The American Society for Testing and Materials (ASTM) defines coal as "readily combustible rock containing more than 50 weight per cent and more than 70 volume per cent of carbonaceous material, including inherent moisture formed from compaction and induration of variously altered plant remains similar to those in peat. Differences in the kinds of plant materials (type), in degree of metamorphism (rank), and in the range of impurity are characteristics of the varieties of coal".

The classification of coals by rank according to their degree of metamorphism or progressive alteration in the natural series from lignite to anthracite disregards the mineral matter and therefore is only a beginning in assessing the quality of coal. According to the ASTM system of classification of coals, rank is a function of heat value measured and expressed in Btu per pound and fixed carbon determined by prescribed methods. Definitions of the various ranks are summarized in Figure 2 and detailed in Appendix A. The definitions compare theoretically mineral-matter-free coal with respect to fixed carbon and volatile matter on a dry basis, and/or the heat value on the inherent moisture basis.

Coal quality refers to those characteristics that affect the potential end use of a coal. Coal quality is essentially determined by the nature and amount of organic matter, mineral matter and moisture. Although quality parameters differ according to the anticipated use of the coal, the following are common: proximate analysis (ash, moisture, volatile matter and fixed carbon by difference), sulphur and heating value. These parameters are usually reported on an as received basis; therefore, the heating value or fixed carbon, as reported, cannot be used directly for rank determination. Samples for quality determination could represent seam sections, run-of-mine-coal or cleaned coal; it is important, therefore, to specify the origin.

The three principal uses for coal are power generation, metallurgical coke and chemical feedstocks including coal conversion. Each of these uses requires certain coal characteristics and, in addition, is affected by various quality parameters. These are briefly described below. The one common factor is that ash and moisture are diluents which increase the handling and transportation costs.

The net heating value of a coal at the lowest cost is the prime consideration for thermal use. Moisture and ash reduce the heating value and increase the cost of coal handling and ash disposal. In addition, ash fusion temperatures are important in boiler and furnace design. Sulphur becomes a problem in the flue gases, where SO_2 emissions have to meet certain environmental standards. Sulphur combined with moisture will increase corrosion in the low temperature parts of the system. Both sulphur and chlorine can form compounds with sodium and potassium, that have very low fusion temperatures. These compounds slag and can foul boiler heating surfaces, particularly in stokerfed boilers. Grindability of the coal is particularly important where pulverized-fuel-fed boilers are contemplated. Although volatile matter contributes to the heat generated, the amount must be known since it affects the furnace design.

Coal for metallurgical coke production is generally limited to the bituminous class; only a narrow spectrum within this class can be used directly, the rest are usually blended. The ash content must be low; this is usually achieved by cleaning the coal in preparation plants of various designs. Sulphur, phosphorus and alkalies must be very low. The proportion of reactive constituents must be optimized in order to provide fluidity to the coal. The measurement of fluidity is indicative of a coal cementing ability, a prerequisite for strong coke structure. The coal must also have acceptable swelling characteristics.

For coal conversion, coals from anthracitic to lignitic can be used but

VM% *	FC% *	CLASS	GROUP	CALORIFIC VALUE **	
				Btu per lb	MJ/kg
		ANTHRACITIC (1)	META — ANTHRACITE		
2	98				
			ANTHRACITE		
8	92				
			SEMIANTHRACITE		
14	86				
		BITUMINOUS (2)	LOW VOLATILE BITUMINOUS		
22	78				
			MEDIUM VOLATILE BITUMINOUS		
31	69				
			HIGH VOLATILE A BITUMINOUS		
				14 000	32.6
			HIGH VOLATILE B BITUMINOUS		
				13 000	30.2
			HIGH VOLATILE C BITUMINOUS		
				11 500	26.7
		SUBBITUMINOUS (4)	SUBBITUMINOUS A (3)		
				10 500	24.4
			SUBBITUMINOUS B		
				9 500	22.1
			SUBBITUMINOUS C		
				8 300	19.3
		LIGNITIC (4)	LIGNITE A		
				6 300	14.7
			LIGNITE B		

* Dry, mineral-matter-free basis.
** Moist, mineral-matter-free basis.
(1) Non-agglomerating; if agglomerating classified as low volatile bituminous.
(2) Commonly agglomerating.
(3) If agglomerating classified as high volatile C bituminous.
(4) Non-agglomerating.
VM : Volatile matter
FC : Fixed carbon

Figure 2. Summarized classification of coal by rank.

coals with a high proportion of volatile matter are preferred for gasification along with low sulphur content. Liquefaction involves hydrogenation, therefore coals with low oxygen content (low rank) are preferred; some hydrogen will be consumed in reactions with oxygen, nitrogen and sulphur.

The susceptibility of a coal to spontaneous combustion is dependent upon the amount of volatile matter, pyritic sulphur, moisture, and weathering characteristics or friability. Lower rank coals, therefore, are generally more susceptible to spontaneous combustion.

An evaluation of the nation's coal resources should not be concerned with just quantity but must include consideration of the inter-relation of the many characteristics of coal. Coals of similar rank can differ significantly when quality characteristics are considered. Moreover, the potential useable resource may be critically limited because of unfavourable characteristics inherent in some coals. Some of the more common inter-relations of rank, quality and end use are shown in Table 3.

Assessment of Rank and Quality of Canadian Coals

In this report the rank and quality of Canadian coals are reviewed with respect to the RESOURCES, RECOVERABLE COAL - Level 2 (see Figure 3) and MARKETED COAL.

Coal Resources

Canada's coal resources are very diverse in both rank and quality. Every rank is known to occur and the range of quality characteristics is very broad. The distribution of coalfields and coal occurrences in Canada by rank, is shown in Figure 4. The following summary gives the distribution by provinces and territories of Canada's coal resources by rank, together with some of their more common quality characteristics.

Nova Scotia

Mainly high volatile bituminous; some medium volatile bituminous; high sulphur content; agglomerates.

New Brunswick

High volatile A bituminous; very high sulphur content.

Ontario

Lignitic; high moisture content; low sulphur content.

Manitoba

Lignitic; similar to Saskatchewan.

Saskatchewan

Lignitic; low sulphur content; sodium content is variable and can pose a problem in some areas.

Alberta

Semianthracite; low sulphur content.

Low and medium volatile bituminous; high ash content except in northwest part; low sulphur content; agglomerates.

High volatile A, B and C bituminous; low sulphur content.

Subbituminous (all groups) and lignite A; low sulphur content.

British Columbia

Anthracitic (all groups); high ash content; low sulphur content.

Low and medium volatile bituminous (eastern B.C.); low sulphur content; high ash in southeastern part; agglomerates.

High volatile A bituminous (Vancouver Island); high sulphur content; variably agglomerating; high ash content.

High volatile B and C bituminous (south central B.C.); high ash content; low sulphur content; agglomerates.

Subbituminous B; high ash content; low sulphur content.

Lignite A (Hat Creek); high ash content; low sulphur content.

Yukon Territory, Northwest Territories

Widespread occurrences of mainly low rank coals; variable quality characteristics as determined on mostly poor samples from outcrop.

Ranges for proximate analysis determinations, calorific values and sulphur content of Canadian coal resources by province and areas are presented in Table 4.

TABLE 3
Inter-relations of Rank, Quality and Use

Coal of this rank: Class	Coal of this rank: Group	Generally has these qualities	and has these potential uses or these characteristics	Depending on qualities such as:
Anthracitic	All groups	Relatively high calorific value	As a thermal coal	Quantity of ash, sulphur and other deleterious constituent and the extent to which they can be removed or suitably reduced by beneficiation processes; ash fusibility
		Non-agglomerating	Does not coke	
		Low moisture content	Stores and transports well	
		High fixed carbon content	Source of carbon	
Bituminous	All groups	Variably agglomerating	As a blend or directly for making metallurgical coke	Sulphur content and extent to which it can be removed or reduced by beneficiation processes; coal type
		Relatively high calorific value	As a thermal coal	Comments at top of column apply here as well
		Low moisture content	Stores and transports well	
	Hv A, B and C	Fairly high volatile matter content	For gasification or liquefaction	
Sub-bituminous	All groups	Non-agglomerating	Does not coke	
		Moderately high calorific value	As a mine-site thermal coal	Comments at top of column apply here as well
		High moisture content	Does not store or transport well; subject to spontaneous combustion	
		High volatile matter content	For gasification or liquefaction	
Lignitic	All groups	Non-agglomerating	Does not coke	
		Relatively low calorific value	As a mine-site thermal coal	Comments at top of column apply here as well
		High moisture content	Does not store or transport well; subject to spontaneous combustion; may necessitate drying before use	

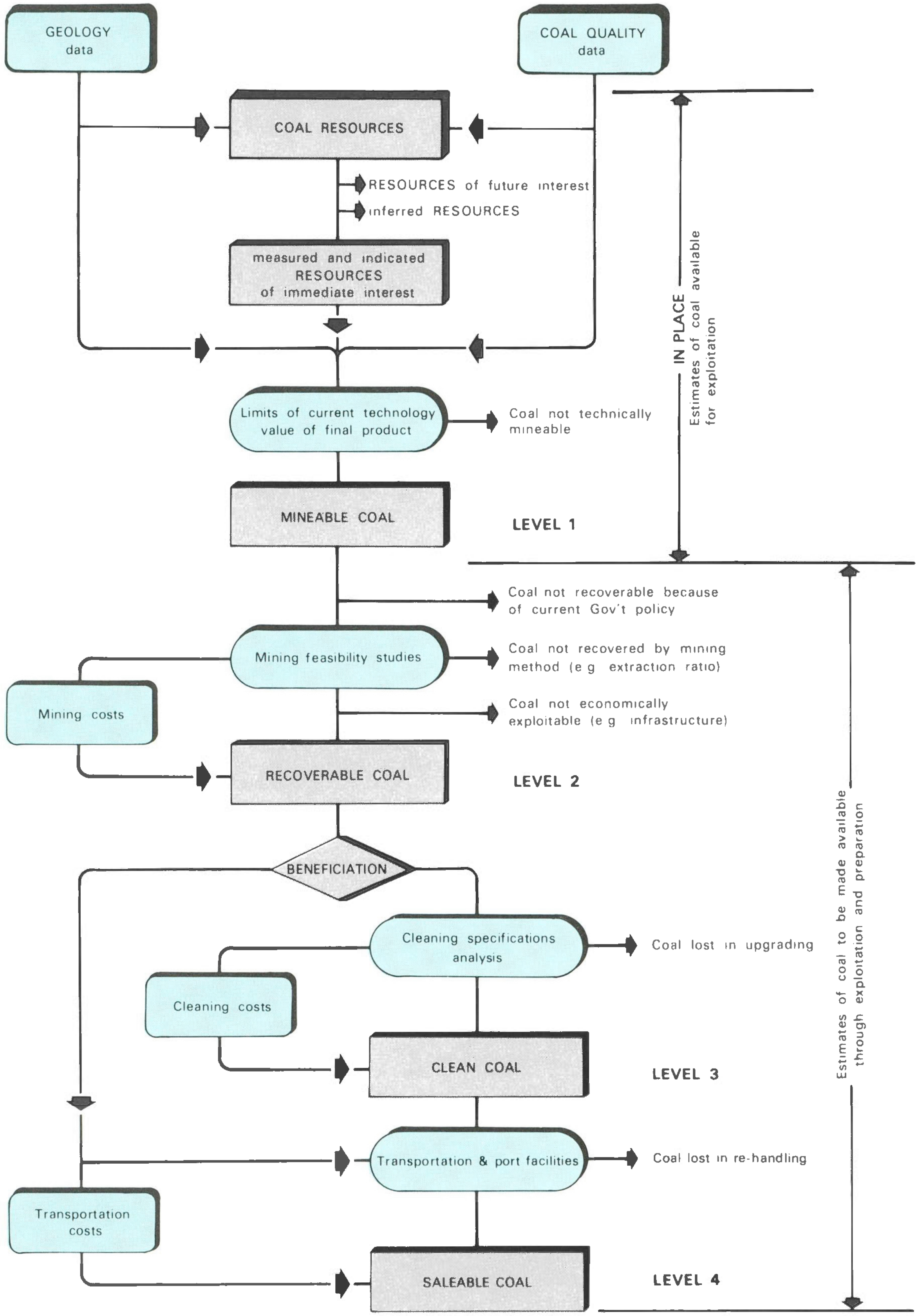

Figure 3. Coal resources to reserve categories.

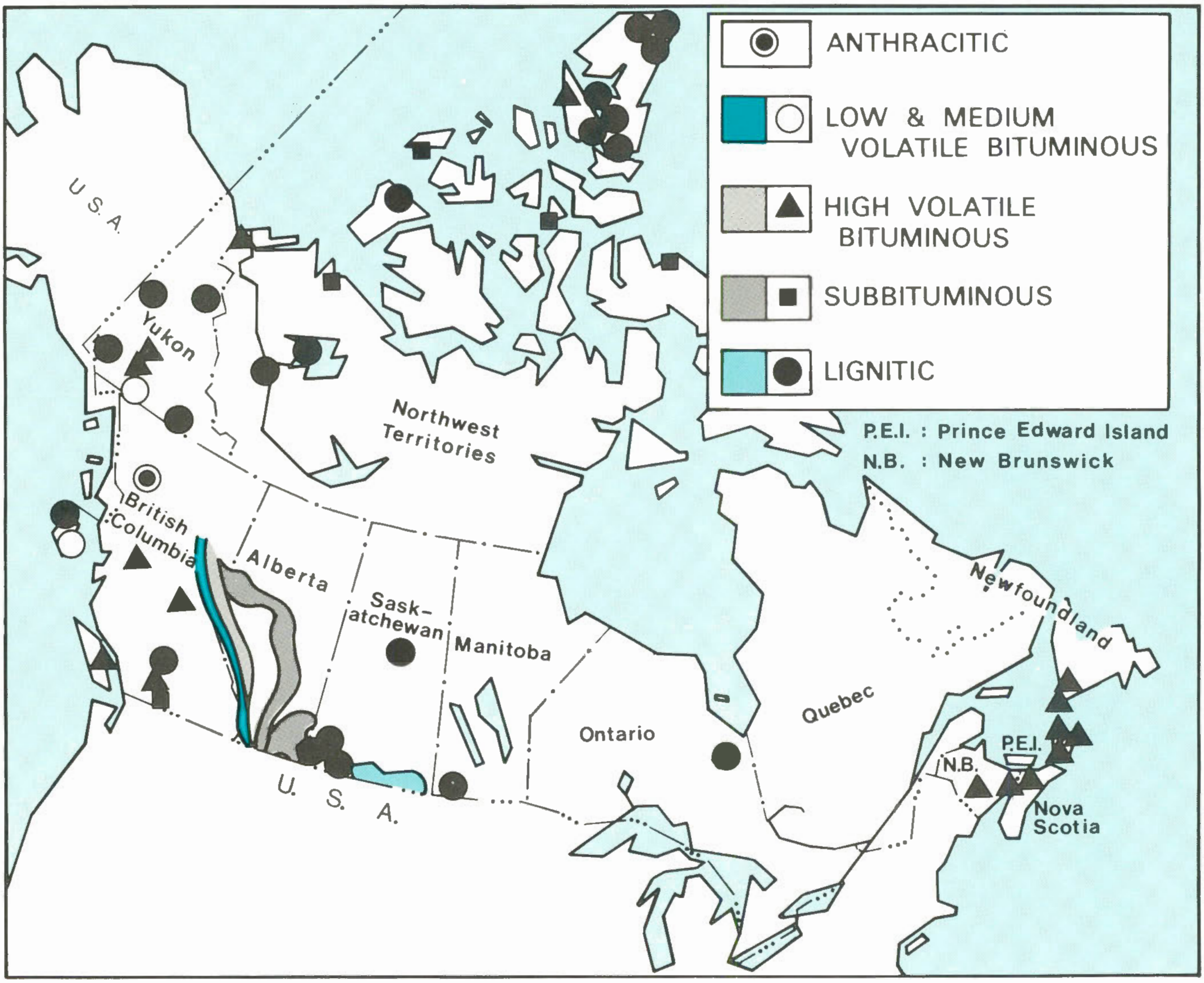

Figure 4. Occurrences of coal in Canada by rank.

TABLE 4
Rank and Quality of Canadian Coal Resources (1978)

Area	Rank[1]	Proximate Analysis %[2] M	A	VM	Sulphur %	Heating Value (m.b.)*MJ/kg
NOVA SCOTIA						
Sydney	hvAb	2- 4	7-10	32-36	1-4	27.9-30.2
Other	mvb	1- 3	15-25	22-27	0.5-2	24.4-29.1
	hvAb	2- 6	9-15	32-37	2-5	26.7-31.4
	hvCb, hvBb	6-10	11-15	35-38	6-8	20.9-20.1
NEW BRUNSWICK	hvAb	2- 6	15-25	30-35	6-10	23.3-29.1
ONTARIO	lig	50.0	6.5	21.5	0.7	14.0
SASKATCHEWAN						
Estevan	lig	27-32	13-25	22-25	0.2-0.6	13.0-15.4
Willow Bunch	lig	25-32	14-30	20-25	0.2-0.6	12.1-15.1
Wood Mountain	lig	24-28	22-35	18-23	0.2-0.6	10.7-13.7
Cypress	lig	20-28	22-45	15-23	0.2-0.6	8.8-13.7
ALBERTA(3)						
Plains						
a) Eastern	sub C	24-31	5-10	27-30	0.3-0.7	17.9-21.2
b) Central	sub B	17-23	6-12	26-32	0.3-0.7	20.7-23.3
c) Western	sub A, hvC	8-16	7-13	30-35	0.2-0.7	22.1-27.0
Foothills	hvAb, hvBb	2- 8	7-14	26-37	0.3-0.9	26.3-31.4
Mountain	mvb, lvb sa	2- 4	8-15	10-24	0.3-0.6	29.8-32.6
BRITISH COLUMBIA						
Southeastern	mvb, lvb	2- 4	17-30	10-24	0.3-0.6	22.8-28.6
Northeastern	mvb, lvb	2- 4	20-32	10-24	0.3-0.6	25.8-27.9
South central	sub, lig	20-23	8-33	24-30	0.4-0.6	11.6-22.1
	hvBb	6-10	14-18	32-36	0.4-0.5	20.9-25.6
Other	hvAb	3- 5	10-14	30-36	0.5-2.5	26.7-29.1

* Moist basis:

(1) lig = lignitic; sub A = subbituminous A; sub B = subbituminous B; sub C = subbituminous C; hvAb = high volatile A bituminous; hvBb = high volatile B bituminous; hvCb = high volatile C bituminous; lvb = low volatile bituminous; mvb = medium volatile bituminous; sa = semianthracite.

(2) Proximate analysis is the determination by prescribed methods, of moisture (M), ash (A), volatile matter (VM), and fixed carbon by difference (FC).

(3) Data provided by Alberta Energy Resources Conservation Board.

Quality of Recoverable Coal

Recoverable coal is that part of a coal deposit which could be extracted as run-of-mine coal (Fig. 3 and Appendix C). The ranks of coal in this category are the same as those determined for the resource evaluation. The quality, however, could be quite different according to the mining method employed. Selective mining could give a lower ash and sulphur content; dilution of the coal by rock partings, roof or floor strata would increase the ash levels; water drainage in a mine could lower the moisture content; whereas hydraulic cutting and transport would increase the moisture level.

Table 5 gives the rank and basic quality of the RECOVERABLE COAL (Level 2), reported on questionnaires by the coal producers and leaseholders.

TABLE 5
Rank and Quality of Recoverable Coal (1977)[1]

Area	Rank[2]	Proximate analysis %[3] M	A	VM	FC	Sulphur %	Heating Value MJ/kg
Nova Scotia[4]	hvb	1-3	3-5	37-39	54-57	1-3	33-34
New Brunswick	hvb	2-5	20	31	44-77	7	26
Saskatchewan	lig	35	8	26	31	0.6	16
Alberta	sub	17-27	7-21	NA	NA	0.2-0.8	16-22
	h-mvb	1-12	10-27	22-34	42-50	0.3-0.6	24-25
	l-mvb	1-8	8-27	12-25	50-73	0.3-0.9	25-30
British Columbia and Yukon	lig	20	31	25	24	0.4	13
	h-mvb	2-8	12-24	19-30	47-61	0.3-0.4	25-33
	l-mvb	1-7	18-24	17-23	47-62	0.4-0.6	25-35

(1) RECOVERABLE COAL (Level 2) is that part of MINEABLE COAL (Level 1) that could be recovered as run-of-mine coal with current technology and at current market prices. The coal deposit must be legally open to mining, and the necessary infrastructure must be in place or could be amortized through coal sales.

(2) lig = lignitic; sub = subbituminous; hvb = high volatile bituminous; lvb = low volatile bituminous; mvb = medium volatile bituminous.

(3) Proximate analysis is the determination, by prescribed methods, of moisture (M), ash (A), volatile matter (VM), and fixed carbon by difference (FC).

(4) Seam samples - not run-of-mine coal.

NA = Not available.

Marketed Coals

Table 6 presents analyses of marketed coals by province. These coals have been subjected to various degrees of alteration by mining (contamination, dilution, etc.) and by coal preparation techniques. Samples were collected at tipples, wash plants, electric utilities, etc., i.e., the coal was either consigned or had reached its ultimate destination, the consumer. The following are brief descriptions of these coals and the normal market designation.

Coals suitable for coke making are produced in Nova Scotia, Alberta and British Columbia for the metallurgical market. Table 7 presents typical analyses of coals presently prepared for the domestic and export metallurgical markets.

Various qualities of coal are suitable for the thermal coal market and these are currently produced in Nova Scotia, New Brunswick, Saskatchewan, Alberta, British Columbia and the Yukon Territory.

Bituminous coals in eastern Canada are in general characterized by relatively low ash and high sulphur contents whereas in western Canada they are high in ash and low in sulphur.

Semianthracite and low volatile bituminous coals produced in Alberta are generally high in ash, low in sulphur, weakly to fairly agglomerating and are used in blends by the metallurgical industry. These coals burn with a short flame and pulverize readily; they produce a non clinkering ash under normal combustion conditions. In general, they are highly friable.

The medium volatile bituminous coals produced in Alberta and British Columbia are mainly used, after cleaning for metallurgical purposes (Table 7). They are strongly agglomerating and low to high swelling. In general, these coals are more difficult to pulverize than the low volatile bituminous coals; they are very friable and the ashes are non clinkering.

High volatile bituminous coals burn with a medium to long smoky flame and are produced mainly for the thermal market. The Sydney area coals are very high swelling and (following cleaning to reduce the sulphur content) are used in blends for manufacture of metallurgical coke (Table 7). In general, the ash fusion temperatures of these coals are low; they are relatively difficult to pulverize, and are subject to spontaneous combustion.

Subbituminous coals are presently produced in Alberta and marketed as mined mainly to thermal power plants as they are non caking. These coals have low weather resistance; are subject to size breakdown and spontaneous combustion in storage; and are relatively difficult to pulverize. They are relatively high in ash but low in sulphur. The ash fusion temperatures are low.

Lignitic coals are presently produced in Saskatchewan and mainly marketed as mined to the thermal power industry as they are non-agglomerating; they are high in moisture and ash but low in sulphur. Lignitic coals have low resistance to weathering and are susceptible to spontaneous combustion. High sodium contents associated with Saskatchewan lignite A coal are a matter of concern to the thermal industry. There are large differences between the quality of Saskatchewan lignite resources (Table 4) and that of marketed lignites (Table 6) particularly in ash content. These differences are believed to be largely the result of selective mining.

Quantitative Assessment of Canada's Coal Resources

The term "coal resources" is defined as being all coal in the ground as it occurs under any and all circumstances. However, in this report coal that occurs in very thin seams or at excessive depths from surface is not considered to be of immediate or near future interest and is excluded from resource considerations. The parameters applied to the coal resource estimates (Table 8) are explained in Appendix B. The classification scheme (Figure 5) recognizes nine categories but estimates are presented for only seven categories as attention has not yet been directed toward the speculative resources. It should be noted that coal reserves discussed later in this report are a portion of the measured and indicated resources and are not additional to the resources.

Data Base

The data base used for quantitative estimation of Canada's coal resources has been generated principally by the following activities: exploration, development and mining undertaken by industry; geological investigations by provincial agencies and by

TABLE 6
Quality of Marketed Coal (1978)[1]

Area	Rank[2]	Proximate Analysis %[3] M	A	VM	Sulphur %	Heating Value (m.b.)* MJ/kg
NOVA SCOTIA						
Sydney	hvAb	1.1-10.6	2.4-20.0	28.0-37.8	0.6-5.3	23.8-34
Other	hvAb	1.5-3.7	11.2-26.4	23.5-36.2	1.0-8.5	23.7-28
	hvBb	5.4-5.6	7.3-16.9	34.6-37.1	5.4-7.3	26.0-29
NEW BRUNSWICK	hvAb	0.6-8.2	14.0-24.0	27.8-34.5	6.1-10.7	26.0-29
SASKATCHEWAN	lig	26.0-28.5	7.2-18.1	26.2-31.6	0.4-0.6	15.6-18
ALBERTA						
Plains	sub B	17.6-20.1	7.4-13.6	25.8-31.1	0.2-0.5	18.2-21
	sub C	22.8-25.0	5.8-10.7	28.2-30.4	0.3-0.4	17.9-20
Foothills[4]	hvCb	8.0-9.0	8.0-9.0	33.0-35.0	0.2-0.3	24.2-24.4
Mountains	mvb	3.0-5.3	8.6-11.6	20.2-26.2	0.2-0.4	29.9-31
	lvb	6.0-6.6	7.4-7.9	16.1-17.9	0.4-0.5	30.3-36
	sa	4.6-7.4	5.9-14.4	11.1-11.4	0.7-0.8	28.7-33
BRITISH COLUMBIA						
Southeastern	mvb	3.4-9.4	7.9-21.5	17.7-24.5	0.2-0.5	24.8-31

* mb = moist basis.

(1) Analyses are those reported in Analysis Directory of Canadian Coals Supplement No. 3 (1978) unless otherwise indicated.

(2) lig = lignitic; sub A = subbituminous A; sub B = subbituminous B; sub C = subbituminous C; hvBb = high volatile B bituminous; hvCb = high volatile C bituminous; lvb = low volatile bituminous; mvb = medium volatile bituminous; sa = semianthracite.

(3) Proximate analysis is the determination, by prescribed methods, of moisture (M), ash (A), and volatile matter (VM).

(4) Analyses from the Alberta Research Council.

TABLE 7
Typical Analyses of Canadian Coking Coals Prepared for Domestic and Export Markets

Province		Nova Scotia	Alberta		British Columbia
Area		Sydney area	Mountains		Southeastern
Rank		hvAb	mvb	lvb	mvb
Proximate analysis (db)					
Ash	%	3.7	9.5	7.7	9.1
Volatile matter	%	34.3	25.5	18.4	22.7
Fixed carbon	%	62.0	65.0	73.9	68.2
Sulphur (db)	%	1.24	0.30	0.43	0.35
Gieseler plasticity					
Start temp.	°C	392	417	460	434
Final temp.	°C	476	482	480	485
Melting range	°C	81	65	20	51
Max. fluidity	ddpm	27 500	435	2	50
Ruhr dilatation (max.) ..	%	203	49	NIL	16
Free swelling index		8	5	5	7
Petrographic indices					
Mean reflectance (R_o).	%	0.98	1.06	1.56	1.32
Total reactives	%	86	64	71	68
Total inerts	%	14	36	29	32
Balance index	CB1	0.40	1.50	3.93	2.35
Strength index	S1	3.43	3.85	7.02	5.65
Stability index (predicted value) ..		35	46	50	55
Ash analysis (db)					
P_2O_5	%	0.1	0.8	1.9	0.8
Na_2O - K_2O............	%	1.6	1.7	0.8	0.6
Al_2O_3	%	21.4	25.9	29.0	30.8
MW - Coking pressure -	psi	0.5	1.0	4	1.0

From private communication with J.C. Botham, CANMET.

TABLE 8
Estimates of Coal Resources in Canada (1978)
(megatons)

Area	Coal Rank[1]	Resources of immediate interest			Resources of future interest		
		Measured[2]	Indicated[2]	Inferred	Measured	Indicated	Inferred
Nova Scotia[3]							
Sydney	hvb	175	502	719	-	-	-
Other	hvb	48	41	38	3	50	128
Subtotal	hvb	223	543	757	3	50	128
New Brunswick[4]							
Minto	hvb	18	2	-	-	-	-
Other	hvb	14	14	1	-	-	-
Subtotal		32	16	1	-	-	-
Ontario[5]	lig	218	-	-	-	-	-
Saskatchewan[6]							
Estevan	lig	310	497	437	41	519	6 998
Willow Bunch	lig	748	1 044	1 420	68	1 704	10 388
Wood Mountain	lig	278	733	1 114	44	1 447	5 665
Cypress	lig	162	407	465	8	243	461
Subtotal		1 499	2 681	3 436	161	3 913	23 512
Alberta[7]							
Plains	sub	30 000[8]	-[9]	102 000[10]	-	-	198 000[11]
Foothills	hvb	1 300	-	7 700	-	-	-
Mountains	lvb-mvb	8 000	-	19 000	-	-	-
British Columbia[12]							
Southeastern	lvb-mvb	6 286	9 436	36 317	-	-	-
Northeastern	lvb-mvb	996	462	7 719	-	-	-
Other	Mainly lig some sub-hvb	1 845	91	7 439	-	-	-
Canada totals	lig	3 562	2 772	10 875	161	3 913	23 512
	sub	30 000	-	102 000	-	-	198 000
	hvb	1 555	559	8 457	3	50	128
	lvb-mvb	15 282	9 898	63 036	-	-	-

(1) lig = lignitic; sub = subbituminous; hvb = high volatile bituminous; mvb = medium volatile bituminous; lvb = low volatile bituminous.

(2) Includes the reserves presented in Tables 9 and 10.

(3) Based on federal/provincial drilling program and Devco data.

(4) Based on information provided by New Brunswick Department of Natural Resources.

(5) Based on EMR study.

(6) Based on federal/provincial coal resource evaluation program.

(7) Estimates for Alberta have not been prepared by EMR. The figures presented in this table are those reported by Alberta Energy Resources Conservation Board, Report 79-31, December 1978. The ERCB's parameters, evaluation methodology and reporting terminology differ from the EMR system and a direct correlation between the two systems is impossible. For this table the following accommodations have been made:

(8) ERCB "established resources" are reported as EMR "measured resources"; it is recognized these figures include some undetermined amounts that EMR would report as "indicated" and/or "inferred".

(9) There is no ERCB category comparable to EMR "indicated"; such coal is included either in EMR "measured" or "inferred".

(10) EMR "inferred" = ERCB "total resource" (330 gigatons) less the deep coal resources (198 gigatons; see footnote 11) and less the ERCB "established resource" (30 gigatons); some might belong in the "indicated" category.

(11) Deep coal resources between 200 and 600 m deep (Yurko, 1976).

(12) Based on evaluations by EMR, British Columbia Ministry of Mines and Petroleum Resources and British Columbia Hydro.

(-) Not determined.

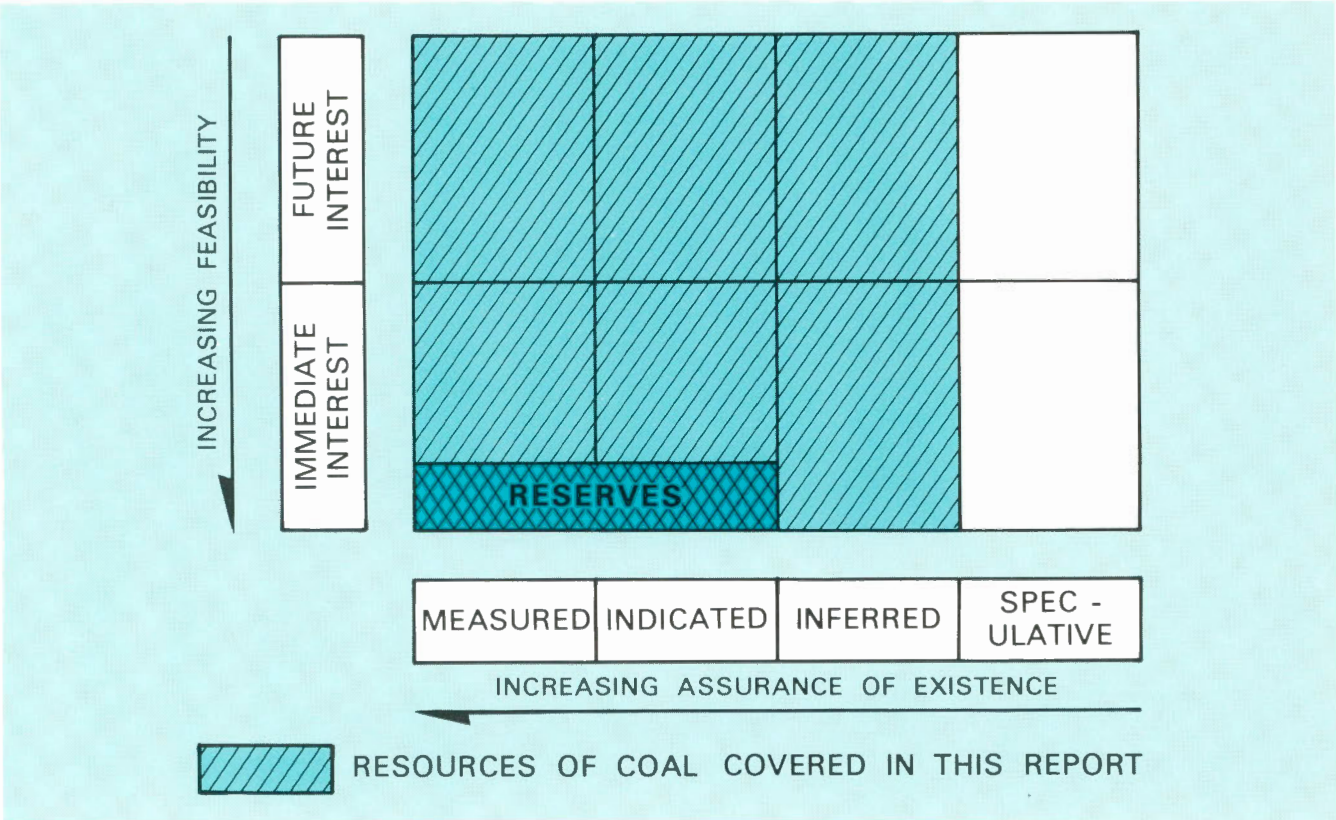

Figure 5. Coal resource classification scheme.

the Geological Survey of Canada; and exploration programs in selected areas that have been funded largely by the federal Department of Energy, Mines and Resources and the Department of Regional Economic Expansion.

These programs can be divided broadly into two categories; firstly, those concerned with regional and local mapping, and secondly, those devoted to the detailed stratigraphy of the coal beds. The first category identifies the location, areal extent and the structural setting of sedimentary rocks which contain coal seams. This information indicates areas most suitable for exploration. Programs in the second category establish the presence, number, age, thickness variations, areal extent, continuity and correlation of seams in many regions of Canada. Programs of both kinds are essential to an objective inventory of coal resources. It is axiomatic that the more complete the data base, the more reliable and useful the inventory.

Resource Estimates

The following estimates of coal (Table 8) are generally considered to be conservative and should not be interpreted as representing the ultimate coal potential of the nation. The quantities of coals and the categories into which they are classified reflect the current knowledge of Canada's coal resources and are therefore subject to change as further efforts are devoted to building a comprehensive national geoscience data base.

While eight provinces contain coal deposits, by far the largest deposits are found in the three western provinces of Alberta, British Columbia and Saskatchewan. With respect to the measured resources, 94 per cent of the lignitic, 100 per cent of the subbituminous, 84 per cent of the high volatile bituminous and nearly 100 per cent of the low and medium volatile bituminous coals are located in the three western provinces.

Excluded from the resource estimates are Newfoundland, Manitoba and all of Canada north of 60°N latitude. Very limited information is available concerning the coal deposits in these areas and such resources as could be estimated would be speculative. There is every indication that the resources of northern Canada are large and, upon further investigation and delineation, will eventually become a significant part of future resource estimates.

Resources by Province

Newfoundland (Figure 6)

At various times between 1897 and 1948, small amounts of surface exploration, drilling and underground exploration were carried out on both the Howley and St. George's deposits. These investigations showed the presence of strongly faulted Pennsylvanian coal beds with steeply dipping, high ash coal seams, rarely more than three feet thick and commonly having shale partings. These adverse factors discouraged further exploration. Estimates of the coal resources have not been included in this report because of lack of sufficient information.

Nova Scotia (Figure 6)

The estimates of resources in Nova Scotia are based largely on data from a recent federal-provincial drilling program together with data provided by the Cape Breton Development Corporation. The Sydney Coalfield is by far the most important in the province and is estimated to contain 223 megatons of measured resources, 543 megatons of indicated resources and 757 megatons of inferred resources of mainly high volatile bituminous coal. Only a very small part of the field is on land with the bulk of it beneath the Atlantic Ocean. The coal, like that of all fields in Nova Scotia, is Pennsylvanian in age. Two seams, the Harbour and the Phalen, have been exploited more extensively than others because of their lower sulphur content and greater mineable thickness. The Pictou, Springhill and Joggins coalfields have been mined extensively. The remaining resources in each field are relatively small with some being difficult of access because of the presence and dangerous condition of old mine workings.

There are four small coalfields along the west coast of Cape Breton Island. They are Port Hood, Mabou, Inverness and St. Rose-Chimney Corner. The quality of the coal, structural conditions and the extensive submarine position of these small fields have restricted exploration and development in this area.

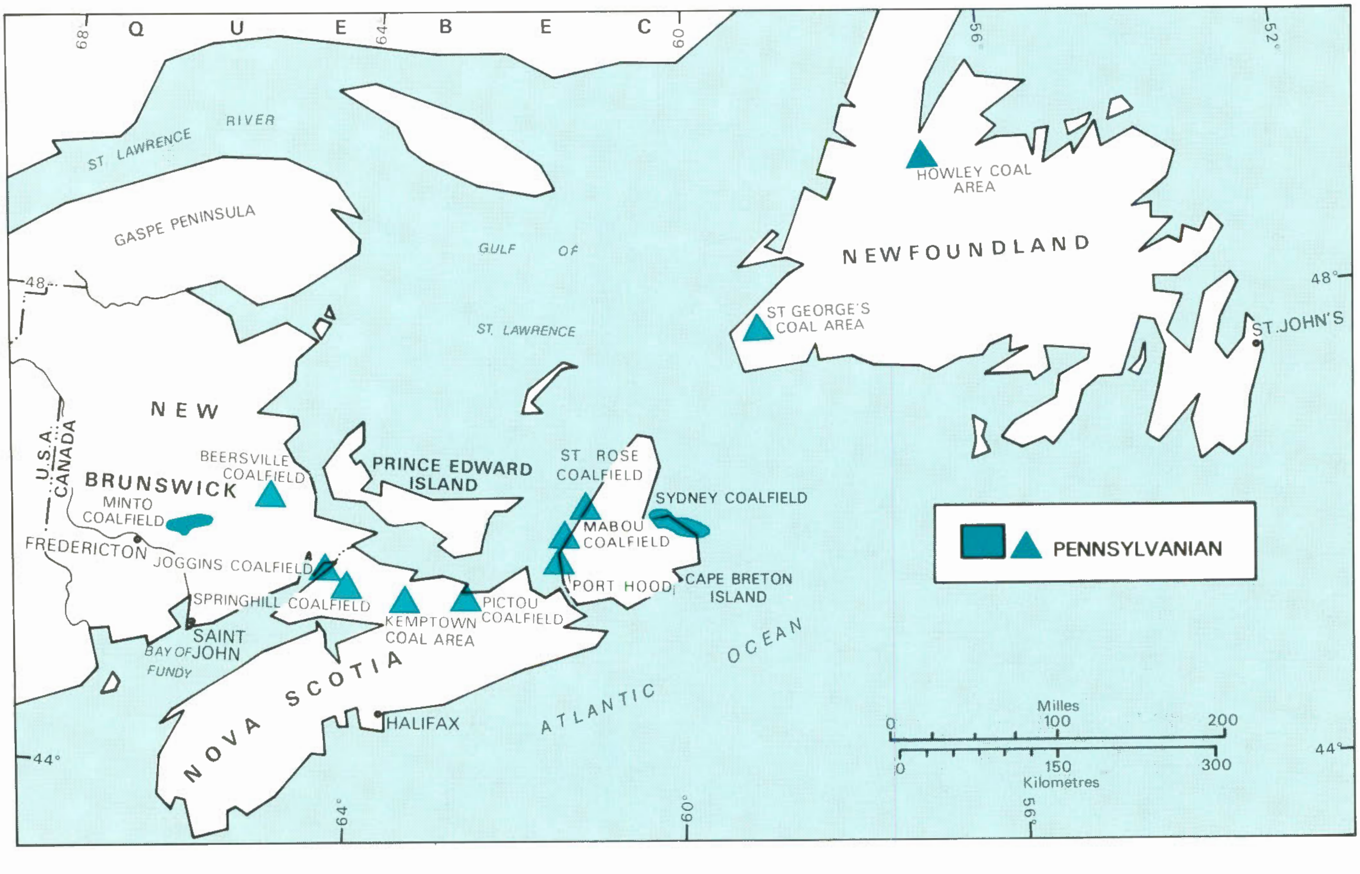

Figure 6. Coal deposits of Newfoundland, Nova Scotia, and New Brunswick, by age.

New Brunswick (Figure 6)

The only currently productive coalfield in New Brunswick is the Minto Coalfield which contains one seam averaging 0.45 m thick. The better part of the field has been mined out and the remaining measured resources are estimated to be 18 megatons.

Recent drilling about 80 km northeast of the Minto Coalfield has delineated two small coalfields, each containing one thin seam and totalling some 14 megatons of measured resources.

A joint federal-provincial drilling program is in progress to explore for additional coalfields in the province.

Ontario (Figure 7)

A thin, Lower Cretaceous sequence called the Mattagami Formation underlies the southern part of the Moose River Basin which lies adjacent to the Canadian Shield of northern Ontario. The sequence consists of sandstones, clays and lignitic coal and the area underlain by it is known as the Onakawana Coalfield. Some 218 megatons of measured resources of high moisture lignitic coal have been delineated over an area of about 39 km^2.

Manitoba (Figure 7)

Thin, lignitic coal seams which are an extension of the deposits in southern Saskatchewan occur in southwestern Manitoba. The few outcrops scattered over the deposit reveal that the seams are too thin to be included within the limits set for resources in this report.

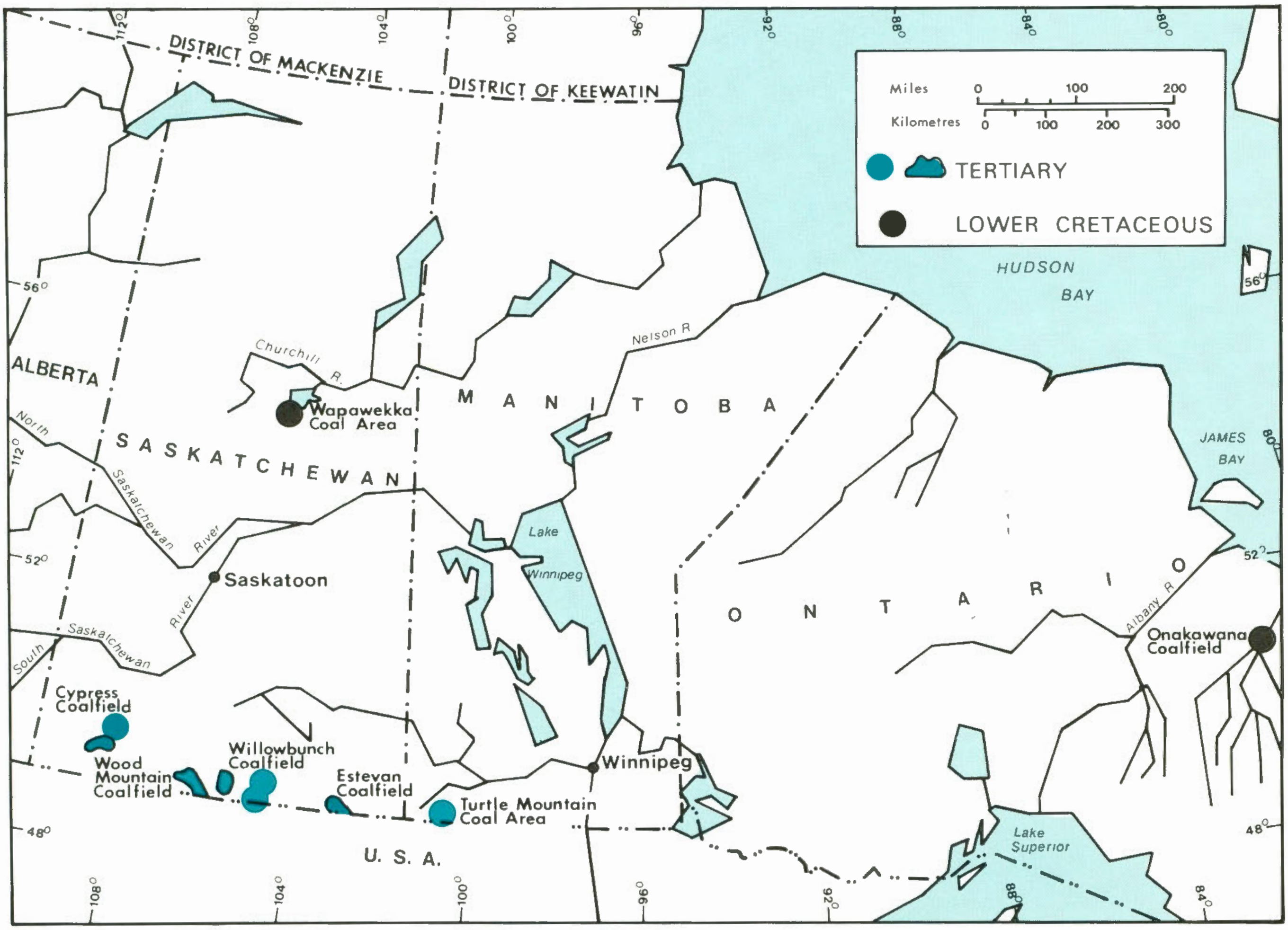

Figure 7. Coal deposits of Ontario, Manitoba, and Saskatchewan, by age.

Saskatchewan (Figure 7)

Seams of Paleocene lignitic coal of mineable thickness are confined mainly to four discrete major basins: Estevan, Willowbunch, Wood Mountain and Cypress. These basins were delineated and evaluated by drilling carried out under a joint federal-provincial coal evaluation program as well as from data provided from drilling by companies. Computer methods of determining resource estimates, developed during the program, have enabled researchers to calculate the resources readily for each 15 m increment of depth from the surface. This refinement in the data breakdown is not shown in Table 8.

Lignitic coal also occurs in the Wapawekka area near Lac La Ronge in central Saskatchewan. The limited data available indicate that the coal is rather high in ash and that the seams rarely attain the minimum mineable thickness of 1.5 m.

Alberta (Figure 8)

Alberta is estimated to have large resources of bituminous and subbituminous coal (Table 8). These estimates have been prepared by the Alberta Energy Resources Conservation Board (1979) according to parameters, evaluation methodologies and a classification scheme that all differ considerably from those of the Department of Energy, Mines and Resources. The Department has not been able to process the large volume of coal data that has been generated within Alberta and is in place of this, presenting the Board's estimates within the context of the Department's reporting system. The accommodations that have been made between the two systems are detailed in the footnotes to Table 8. In general the Board's estimates would tend to be higher than those produced under the Department's system but the extent of the difference is difficult to determine.

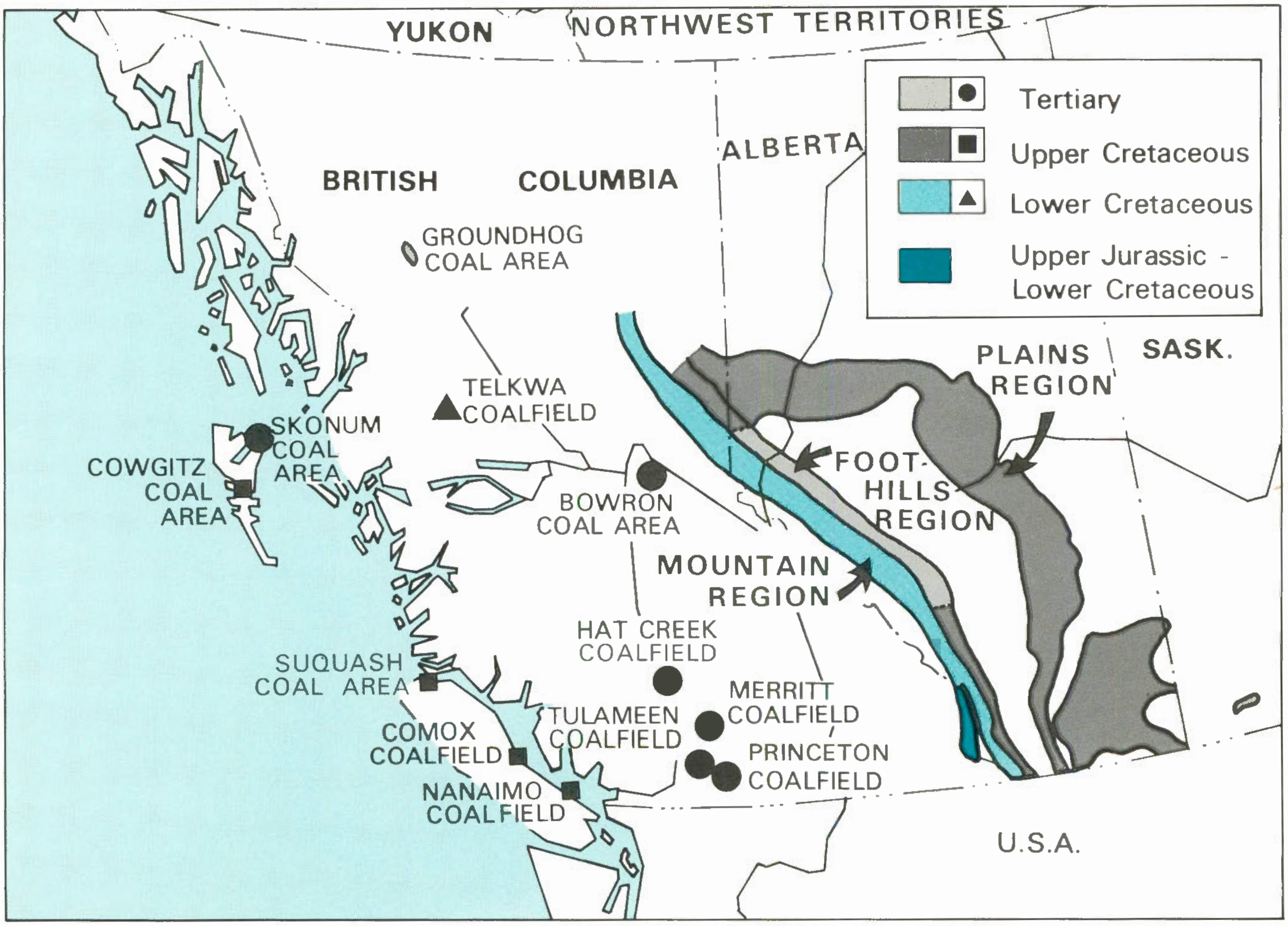

Figure 8. Coal deposits of Alberta, and British Columbia, by age.

The province is divided into three regions, each containing deposits of similar age and characteristics. These are the Mountain, Foothills and Plains regions (Figure 8).

The Mountain Region extends along the eastern flank of the Rocky Mountains, and contains mostly medium and low volatile bituminous coal deposits mainly of Upper Jurassic and Lower Cretaceous age. The coals are commonly friable and the seams are steeply inclined, highly sheared and faulted. In areas of intense folding the seams are often thickened in the hinge areas. Such areas of thick coal seams are of particular interest to mining companies as possible sites for surface mining operations.

The Foothills Region adjoins the eastern edge of the Mountain Region and contains mainly high volatile bituminous coals of Upper Cretaceous and Lower Tertiary ages. They appear to be developed best in the area between the North Saskatchewan and Athabasca rivers. Like their counterparts in the Mountain Region, these coal beds have been sheared, faulted and folded. At the outcrop or near the surface anomalous thickening can provide favourable sites for surface mining.

The Plains Region is characterized by generally flat-lying or gently inclined seams of Upper Cretaceous and Lower Tertiary age and mainly of subbituminous rank. Outcrops are uncommon and information about the deposits is largely obtained through drilling. The proximity to surface of some of the seams allows for their recovery by surface mining methods - the method by which almost all the coal in the region is produced.

British Columbia (Figure 8)

Coal deposits are widely scattered through British Columbia. For purposes of discussion the tabulation of resources of the province has been divided into three regions namely, southeastern, northeastern and other.

The coal deposits of southeastern British Columbia are commonly referred to as the Crowsnest Coalfield. This coalfield, mined since 1897, has been extensively explored and is the only area in the province where coal is now being mined. The deposits are Upper Jurassic in age and are part of the southern end of the Mountain Region as described for Alberta with the notable difference that they contain considerably more seams that are of greater thickness than in adjoining areas of Alberta.

The coal deposits of northeastern British Columbia are Lower Cretaceous in age and are the northern extension of the coals that occur in the Mountain Region of Alberta. The region has undergone much exploration in the past several years resulting in significant resource estimates (Table 5) and an indication of large amounts yet to be determined.

Several small basins of Tertiary coal occur in the south-central part of the province, including Tulameen, Princeton, Merritt and Hat Creek Basins. The Hat Creek Basin is by far the most important because of the exceptionally thick (50, 70 and 150 m), near surface, lignitic seams which give rise to very large tonnages in a small area. Jura-Cretaceous deposits occur in the Telkwa and Bowron River areas of central British Columbia. Mining experience at Telkwa over the past 30 years has shown the deposits to be intensely folded and faulted and to be intruded by igneous rocks. Small scale exploration in the Bowron deposit has indicated that the seams are of limited extent and irregular in thickness.

The Jura-Cretaceous deposits of the Groundhog Coalfield in northern British Columbia are little known and poorly understood. Based on areal extent of the deposits and very limited exploration, there appears to be a relatively high potential for low volatile bituminous and anthracitic coals of high ash content. The area has undergone intense deformation which may make mining difficult.

Three small areas underlain by Upper Cretaceous coal deposits occur on the east coast of Vancouver Island. The Nanaimo Coalfield produced coal for many years but is now considered to be completely mined out. The more accessible parts of the Comox Coalfield have largely been mined out leaving the deeper less accessible coal and an area to the north where recent exploration has indicated some potential for near-surface seams. What little is known about the remaining area of Suquash as well as the Cowgitz and Skonun coal areas of Queen Charlotte Islands indicates structural and stratigraphic problems. These low quality coals, locally intruded by igneous rocks (Queen Charlotte Islands), do not appear attractive for exploitation.

Estimates of the coal resources of this province are based on information obtained from the British Columbia Department of Mines and Petroleum Resources and other sources available to the Department of Energy, Mines and Resources.

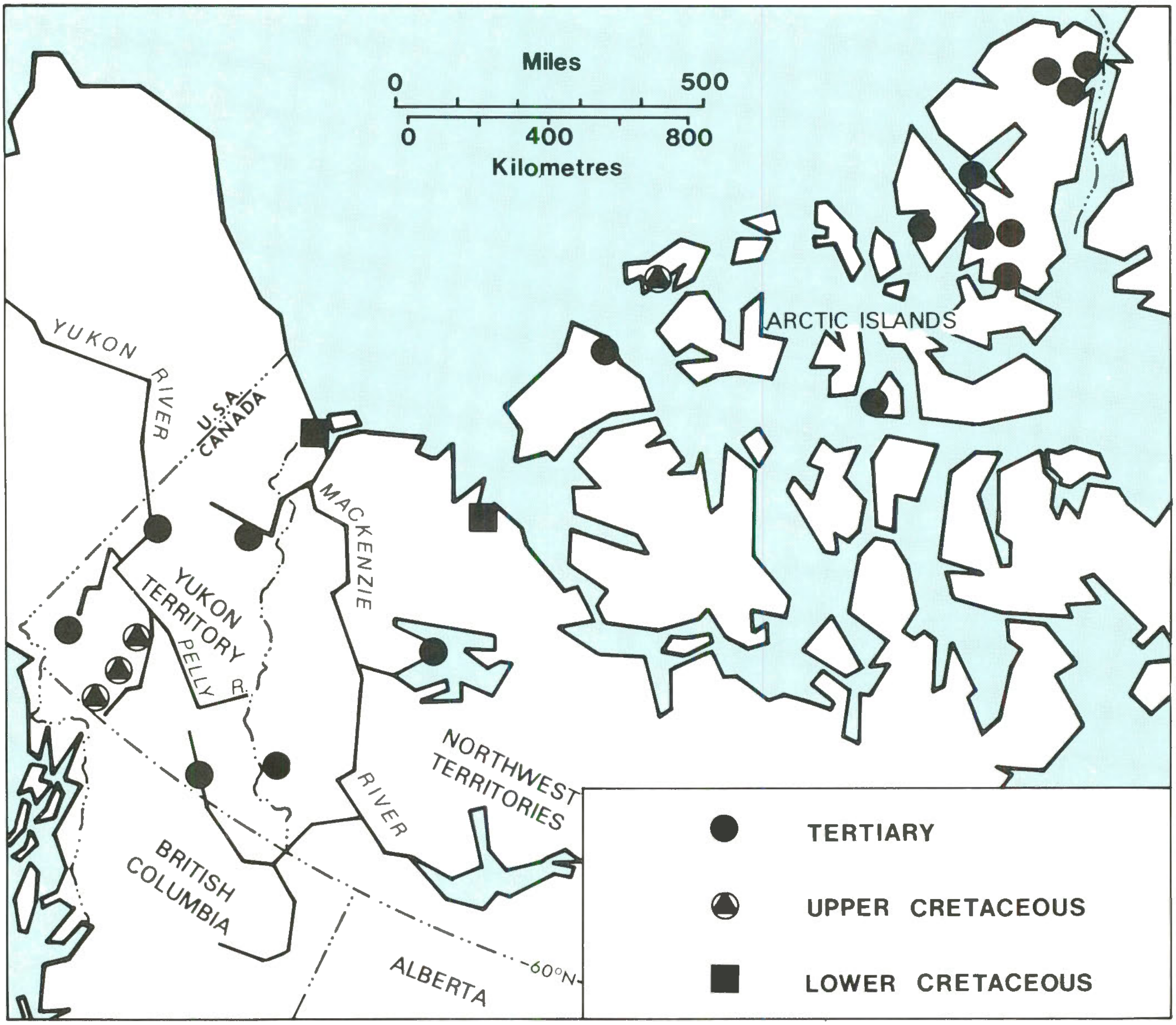

Figure 9. Coal deposits of northern Canada, by age. (seam thickness 1.5 m of greater)

Northern Canada (north of 60° latitude) (Figure 9)

Significant occurrences of coal are widespread in the Canadian north although the information is almost entirely confined to reports of seams exposed in outcrop. Seams up to 9 m thick have been noted, but further details of these occurrences have not yet been reported. As yet not even speculative resources have been estimated for this large region, but such information as exists suggests a very high likelihood of large coal resources.

With few exceptions production has been limited to small scale operations for local consumption at such places as Pond Inlet, Aklavik and Paulatuk in the Northwest Territories and Carmacks, Whitehorse, Burwash Landing and Dawson City in Yukon Territory. The only mines with a recorded production are the Five Fingers, Tantalus and Tantalus Butte mines, all near Carmacks, Yukon Territory. Tantalus Butte mine is the only producing coal mine in all of northern Canada.

Quantitative Assessment of Canadian Coal Reserves

Coal reserves refer to a portion of the measured and indicated resources with due regard to current technology and economics. However, there are many ways of expressing this portion and unfortunately the term "reserves" has been applied rather loosely to various levels, from an in situ tonnage to a saleable product encompassing several quality ranges. Tonnage estimates made available by operating companies and lease holders have been used to derive the figures reported here. Discussions with members of the coal industry and provincial agencies dealing with coal indicated that the definitions for coal reserves tabulated in the 1976 report were too restrictive. Therefore, the reserve levels have been redefined and two separate levels are reported.

Reserve Levels (Figure 3)

The transformation of coal resources to reserves requires a series of technological as well as economic assessments to be made. The stages of assessment and the resulting reserve levels have been chosen to parallel the evolution of a coal prospect into an operating mine, but exclude any marketing considerations since infinite markets at current prices are assumed. Each succeeding assessment stage must be based on a fuller understanding of the coal deposit. While the initial coal resource-base remains constant for a deposit, the amount of coal reported for each successive "reserve" level will be less than in the preceding one.

The first level derived from the measured and indicated resources of immediate interest is based on how much coal can be considered for possible mining using current technology; a broad economic assessment relating coal market-value and the probable mining method must be made. This is Level 1 - MINEABLE COAL. The next stage should be based on feasibility studies giving cost and extraction ratios of mining methods, consideration of infrastructure, mining permits, etc., to give Level 2 - RECOVERABLE COAL. The remaining two levels represent, respectively "clean product" after preparation and "delivered coal" taking into account transportation costs. The definitions for these reserve levels are given in Appendix C and illustrated in Figure 3.

Reserve Estimates

Coal reserves in Canada are given in Tables 9, 10 and 11; both MINEABLE COAL (Level 1) and RECOVERABLE COAL (Level 2) have been reported. The tonnages and coal quality are based on more than 90 per cent response to questionnaires sent to operating mining companies and coal-lease holders, and on published information to January 1, 1978.

The estimates of MINEABLE COAL (Level 1) shown in Table 9 comprise 3 207 megatons of lignitic, 7 328 megatons of subbituminous and 5 556 megatons of bituminous coal. Of these quantities, 82 per cent of the subbituminous and 64 per cent bituminous coal are surface mineable. In the bituminous category of MINEABLE COAL, 3 916 megatons or 71 per cent are estimated to be of coking quality, the remainder is of thermal quality.

RECOVERABLE COAL (Level 2) has been estimated (Table 10) at 2 177 megatons of lignitic, 2 182 megatons of subbituminous and 1 607 megatons of bituminous. About 80 per cent of the reported RECOVERABLE COAL can be mined by surface operations; 1 263 megatons (79 per cent) are estimated to be of coking quality.

Alberta is the only province that regularly publishes an estimate of its coal reserves. The data base, methodology, and definition of "coal reserves" used for these provincial estimates differ substantially from those used in this national assessment. The reserve estimates, reported here, are a summation of the best-available assessments for individual coal deposits, at the national level.

Current Coal Mining Methods in Canada

Coal mining methods in Canada are dependent upon the type of coal mined and the conditions under which it occurs. The rank of the coal, to some degree, limits the end use of the product mined and also the market value. The lignitic and subbituminous coals are used for mine-mouth thermal power generation and have a market value of less than $5 per metric ton for coal at the mine site. On the other hand, some of the low to medium volatile bituminous coals used for coke production have a market value of over $50 per metric ton for clean coal at the mine site. This price differential has a direct bearing on allowable mining expenditures and, therefore, places a limit on the mining methods that may be used.

TABLE 9
1977 Mineable Coal[1] in Canada
(megatons)

Area	Rank[2]	Under-ground	Surface	Total
Nova Scotia	hvb	364	6	370
New Brunswick	hvb		46	46
Ontario	lig		218	218
Saskatchewan	lig		2 150	2 150
Alberta	sub	1 347	5 981	7 328
	h-mvb	424	513	937
	l-mvb	562	958	1 520
British Columbia and Yukon	lig		839	839
	h-mvb	54	492	546
	l-mvb	582	1 555	2 137
Canada total	lig		3 207	3 207
	sub	1 347	5 981	7 328
	bit	1 986	3 570	5 556

1) MINEABLE COAL (Level 1) is that part of the measured and indicated resources of immediate interest within a coal deposit, that can be considered for mining using current technology, and applying broad economic judgment only to the mining method.

2) lig = lignitic; sub = subbituminous; hvb = high volatile bituminous; lvb = low volatile bituminous; mvb = medium volatile bituminous.

TABLE 10
1977 Recoverable Coal[(1)] in Canada
(megatons)

Area	Rank[(2)]	Under-ground	Surface	Total	Proximate analysis %[(3)]				Sulphur %	Heating value MJ/kg
					M	A	VM	FC		
Nova Scotia	hvb	89		89	1-3	3-5	37-39	54-57	1-3	33-34
New Brunswick	hvb		33	33	2-5	20	31	44-47	7	26
Saskatchewan	lig		1 720	1 720	35	8	26	31	0.6	16
Alberta	sub	NA	NA	2 182	17-27	7-21	NA	NA	0.2-0.8	16-22
	h-mvb	84	155	239	1-12	10-27	22-34	42-50	0.3-0.6	24-25
	l-mvb	64	227	291	1-8	8-27	12-25	50-73	0.3-0.9	25-30
British Columbia and Yukon	lig		397	397	20	31	25	24	0.4	13
	h-mvb	NA	NA	51	2-8	12-24	19-30	47-61	0.3-0.4	25-33
	l-mvb	44	860	904	1-7	18-24	17-23	47-62	0.4-0.6	25-35
Canada total	lig		2 117	2 117						
	sub	NA	NA	2 182						
	bit	NA	NA	1 607						

(1) RECOVERABLE COAL (Level 2) is that part of MINEABLE COAL (Level 1) that could be recovered as run-of-mine coal with current technology and at current market prices. The coal deposit must be legally open to mining, and the necessary infrastructure must be in place or could be amortized through coal sales.

(2) lig = lignitic; sub = subbituminous; hvb = high volatile bituminous; lvb = low volatile bituminous; mvb = medium volatile bituminous.

(3) Proximate analysis is the determination by prescribed methods, of moisture (M), ash (A), volatile matter (VM) and fixed carbon by difference (FC).

NA = Not available.

TABLE 11
1977 Coal Reserves in Canada by rank

Rank and area	MINEABLE COAL(1) Level 1	RECOVERABLE COAL(2) Level 2	
	megatons	megatons	Heat value petajoules
LIGNITIC			
Ontario	218	NA	
Saskatchewan	2 150	1 720	27 100
British Columbia	839	397	5 200
Total	3 207	2 117	32 300
SUBBITUMINOUS			
Alberta	7 328	2 182	41 600
BITUMINOUS			
Nova Scotia	370	89	3 000
New Brunswick	46	33	800
Alberta	2 457	530	14 300
British Columbia and Yukon	2 683	955	30 400
Total	5 556	1 607	48 500
Canada total heat value			122 400
BITUMINOUS METALLURGICAL (included in BITUMINOUS above)			
Nova Scotia	258	69	
Alberta	1 521	290	
British Columbia	2 137	904	
Total	3 916	1 263	

(1) MINEABLE COAL (Level 1) is that part of the measured and indicated resources of immediate interest within a coal deposit, that can be considered for mining using current technology, and applying broad economic judgment only to the mining method.

(2) RECOVERABLE COAL (Level 2) is that part of MINEABLE COAL (Level 1) that could be recovered as run-of-mine coal with current technology and at current market prices. The coal deposit must be legally open to mining, and the necessary infrastructure must be in place or could be amortized through coal sales.

NA = Not available.

Basically, there are two classes of mining methods: surface mining - where the material overlying the coal seam is removed in order to gain access to the coal; and underground mining - where the coal itself is mined between the overlying and underlying strata. Surface mining accounted for 85 per cent of the run-of-mine coal produced in 1978; the remainder being mined by underground methods.

Active mining areas and the ranks of coal mined there, are shown on Figure 1. Details on each mine can be found in "Operators List 4, Coal Mines in Canada, 1978, EMR".

Surface mining is capital-intensive and has, generally, a high productivity. Two different methods are commonly used:

(1) Dragline stripping - where the overburden is removed by a dragline and cast back into the mined out area. In this way a furrow is opened up exposing the coal which can then be removed by truck and shovel. When the coal has been recovered, the strip is back-filled with the overburden from the next furrow. This method is commonly called "strip mining".

(2) Truck-and-shovel stripping - where the overburden is transferred by trucks from the pit to specified waste dumps outside the working pit. In this method material handling costs are higher than in "strip mining".

The two methods may be combined where multiple seams are mined. A number of small operators utilize front-end loaders, scrapers and other equipment instead of shovels or draglines.

Underground mining, by comparison with surface mining, is labour-intensive, and, therefore usually results in lower productivity. Access to the coal is achieved by slopes, tunnels or shafts, which are used for transportation and haulage, and for airways. Three basic types of underground mining are currently used in Canada:

(1) Longwall mining - where coal is cut by a shearing machine operating along coal faces up to 215 metres in length. The coal is removed from the face by an armoured-chain conveyor. Development tunnels for longwall faces are driven in the coal while the face is advancing. The length of panels mined by this method is currently 2 100 to 3 300 metres. The overlying strata are allowed to cave behind the powered supports.

(2) Room-and-pillar mining - where a network of tunnels in the coal seam, known as entries and crosscuts, are mined to leave a checkerboard pattern of pillars which may be extracted eventually or left for roof support purposes. Entries and crosscuts are usually cut with a continuous miner and shuttle cars are used to transport the coal to conveyors. In one mine, tunnels are advanced by blasting and coal is moved from the face with slushers. Pillar extraction is currently being carried out by both of the above methods.

(3) Hydraulic mining - where main development roadways are cut for thousands of metres at constant grades to allow for efficient operation of coal transport in open flumes. Pillars hundreds of metres long are formed above the main roadways and are then extracted on a retreating pattern by hydraulic monitors. Coal transport within the one operating mine in southeastern British Columbia is solely by water in open flumes.

In Table 12, coal production in Canada is shown as "run-of-mine" tonnage according to mining method used.

Coal Demand in Relation to Supply and Recoverable Reserves

Demand

To place the estimates of reserves in perspective, the following rough preliminary estimate of coal demand (in Table 13) in Canada has been compiled by the Department of Energy, Mines and Resources from studies of four major coal demand categories:

(1) Electric utility sector;
(2) Canadian steelmaking;
(3) Exports of coking and steam coals; and
(4) Substitution and conversion, mainly in industry.

In Table 13 and Figure 10 the forecast demand shows continual growth for lignitic, subbituminous and bituminous coal. In terms of tonnage the largest increase in demand for Canadian coal is expected for subbituminous coal from the plains region of Alberta, from 7.9 megatons in 1977 to 71.0 megatons in 2000, which represents an average annual increase of about 10 per cent. However, the growth in demand for bituminous coal, although slower is more significant in terms of growing total value of the product.

TABLE 12
1978 Run-of-mine Coal Produced by Mining Method
(in kilotons and as % of total)

	Mining method	Rank*	Maritimes kt	(%)	Saskatchewan kt	(%)	Alberta kt	(%)	B.C. and Yukon kt	(%)	Total by mining method kt	(%)	Total surface or underground kt	(%)
SURFACE	Dragline stripping	lig			5 058	(14)					15 314	(42)	30 849	(85)
		sub					7 765	(21)						
		bit	318	(1)					2 173	(6)				
	Truck and shovel stripping	sub					513	(1)			15 535	(43)		
		bit	87	(0)			5 569	(15)	9 366	(26)				
UNDERGROUND	Longwall	bit	2 602	(7)							2 602	(7)	5 395	(15)
	Room and pillar**	sub					32	(0)			2 793	(8)		
		bit	205	(1)			1 839	(5)	717	(2)				
	Total	lig			5 058	(14)					5 058	(14)	36 243	(100)
		sub					8 310	(23)			8 310	(23)		
		bit	3 212	(9)			7 407	(20)	12 256	(34)	22 875	(63)		

* lig - lignite
sub - subbituminous
bit - bituminous

** Includes hydraulic mine production.

TABLE 13
Forecast of Demand for Canadian Coal*
1977-2000
(megatons)

	1977	1978	1980	1985	1990	1995	2000	Average annual growth % 1977-2000
Lignitic	5.2	5.0	6.0	7.0	20.0	24.0	33.0	8.8
Subbituminous	7.9	8.2	8.0	18.0	40.0	52.0	71.0	10.5
Bituminous	15.0	16.1	22.0	29.0	37.0	49.0	59.0	6.4

* (from Hunt, A.D., 1978)

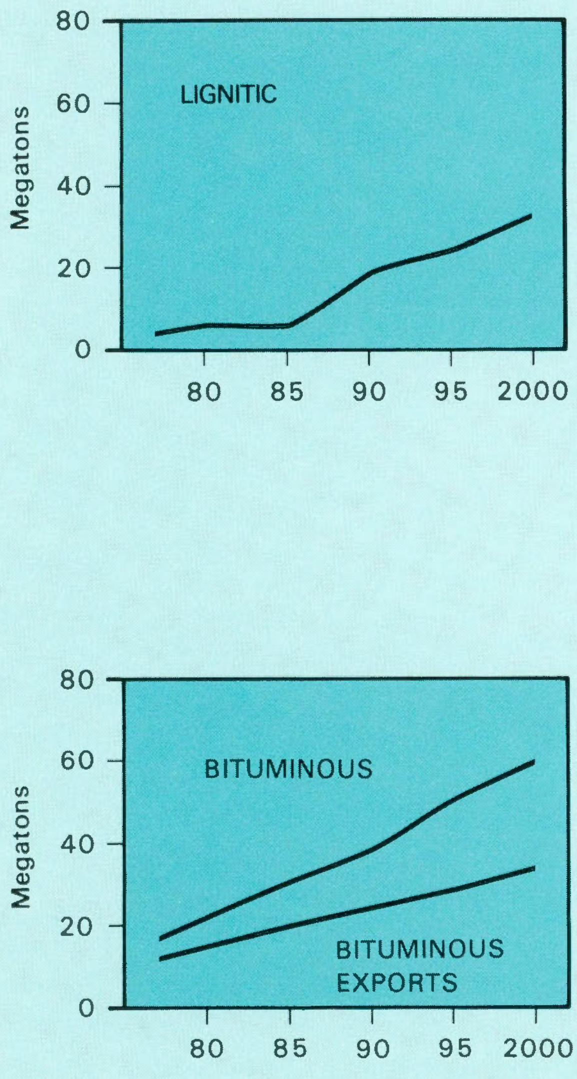

Figure 10. Forecast of demand for Canadian coal by rank.

Supply

A prerequisite of security of coal supply is adequate knowledge of coal reserves and additional resources, and of possible production rates in relation to the future demand for coal.

This report serves as a first step in outlining reserves but, as suggested earlier, knowledge is far from adequate when it comes to estimating production costs. The analysis of neither reserves (i.e. the sources of short-run supply) nor demand is far enough advanced to make possible authoritative answers to the questions continually being asked: "Are Canada's coal reserves sufficient to sustain anticipated demand?" "Will coal supply capability be sufficient to meet future demand?" and "For how long will supply be able to meet demand?".

The estimates of recoverable reserves presented in this report are of the reserves as of December 31, 1977. Because reserves are reported as of a particular point in time, the adequacy of recoverable reserves, given the estimated demand, must be constantly reassessed, because both reserve levels and the demand outlook change over time. For example, reserves increase or decrease for many different reasons:

(1) Price rises can increase reserves; lower prices may decrease them.

(2) New mining technology can add to the reserves by reducing mining costs and by increasing the recovery factor.

(3) Better delineation of a coal deposit through drilling, trenching, sampling and test mining can add to, or subtract from, reserves.

(4) The provision of infrastructure such as railways, ports and townsites could open up now inaccessible areas. Thus MINEABLE COAL (Level 1) could be converted to RECOVERABLE COAL (Level 2).

(5) Permission to mine where currently prohibited by law or government policies would produce new reserves.

Production Capability

A reserve appraisal should include an indication of possible short-term and longer-term production rates in an economically plausible context. Essentially, the objective of a reserve appraisal is to provide an impression about what has to be done to obtain desirable supply levels in future years when they will be needed, so that estimates can be made of how much may have to be spent, and at what rates, to accomplish this.

Estimation and classification of reserves and additional resources are only milestones on the way to providing supply scenarios. To arrive at such scenarios involves detailed study of specific mining areas to estimate the annual production rate likely to be associated with the estimate of recoverable coal for that area. These estimates of future annual production rates are then aggregated by coal type in conjunction with the estimates of recoverable coal. A curve is then constructed that shows the pattern of output from all mines together, fed solely by the reserves established as of December 31, 1977 (as if not a single ton of additional reserves were to be developed after that date).

The gap between this curve and the desired total output level (demand) must be filled by production from reserves yet to be determined; additional output capacity is likely to be required as well. Increasing the output capacity of recoverable coal in today's reserves may close the gap in the near future but will only widen it more quickly in the longer term.

Bituminous Coal

Of the three main classes of coal produced in Canada, bituminous coal has the most complex supply-demand relationship. Exploration and development of coal involve expenditure in time and money. Such expenditure is considerable in the case of bituminous coal. Therefore companies tend to develop only enough reserves and production capability for bituminous coal as is necessary to meet their contract commitments. The demand for Canadian bituminous coal comes from domestic and foreign consumers - for use in both the iron and steel industry (coking coal) and the electric utility industry (thermal coal).

Figure 11 shows the supply capability as of January 1, 1978 for bituminous coal, RECOVERABLE COAL (Level 2) only, as well as the forecast bituminous coal demand. A comparison between supply capability and forecast demand shows that 1977 RECOVERABLE COAL (Level 2) and production capability will not be sufficient to meet demand after 1988. In order to prevent a shortfall between supply and demand after that date,

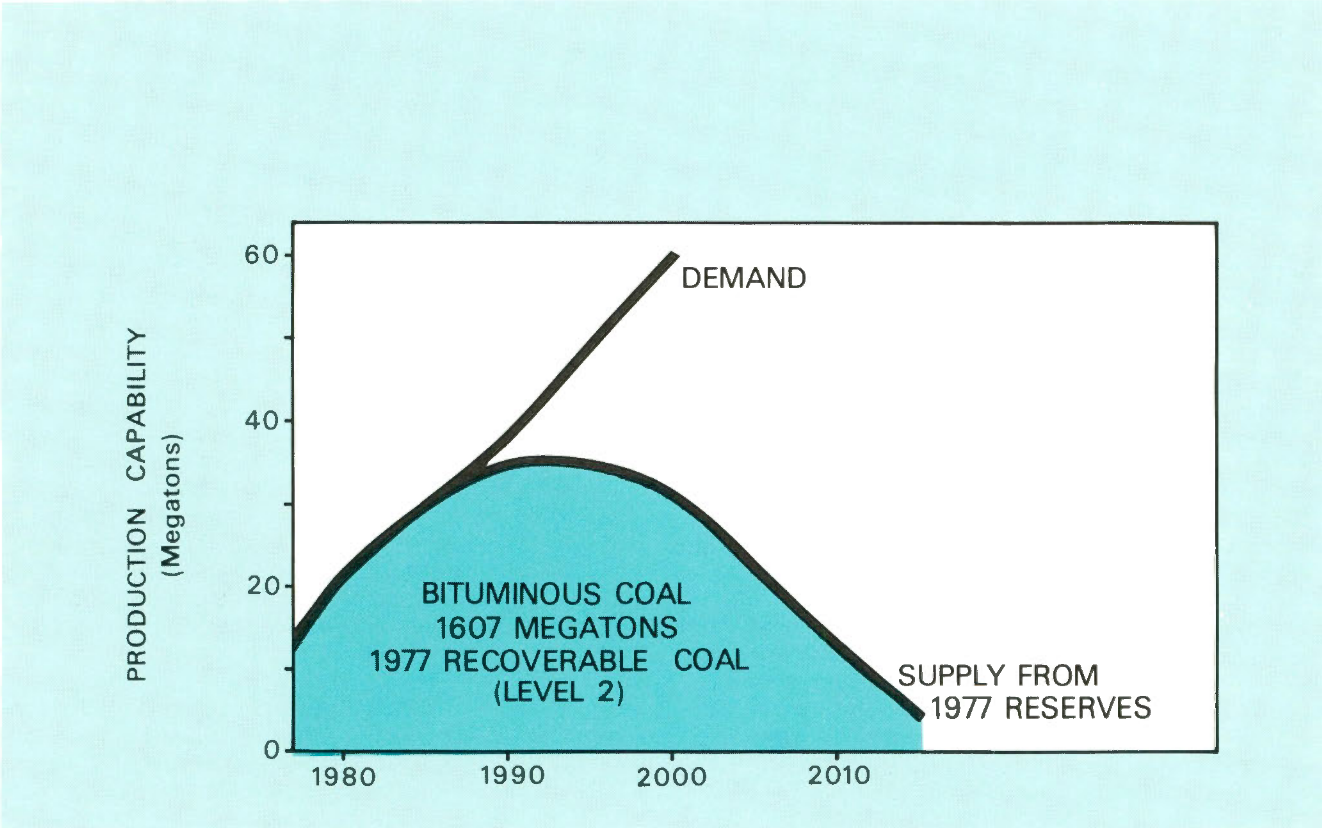

Figure 11. Bituminous coal demand in relation to 1977 RECOVERABLE COAL (Level 2) and supply capability.

the Canadian coal industry must react and increase their RECOVERABLE COAL (Level 2) and production capability. Shortfalls can be averted by further work on coal now reported in the MINEABLE COAL category (Level 1) to the point where RECOVERABLE COAL (Level 2) may be assessed. This process, as previously stated, will involve additional exploration by companies, careful consideration by governments of land use policies, and new investment for infrastructure (i.e. railways, townsites and port facilities).

Subbituminous and Lignite

For subbituminous and lignitic coal, coal companies tend to develop reserves for the long-term. These coals generally occur in flat lying beds in the Plains Region, so that reserves are easier and less costly to develop than for bituminous coal in the mountains of British Columbia and Alberta.

Development of long-term reserves of thermal coal is influenced by the long life span of thermal electric power plants (25 to 40 years). Also, many of the companies involved in the development of thermal coal reserves have the financial resources to take a long-term view (i.e. electric power utilities, oil companies, and energy conglomerates).

Historically in Canada, supply of lignitic and subbituminous coal has tended to follow demand. As thermal coal is produced mainly for captive markets, a balanced supply/demand relationship is expected to continue.

From an analysis of RECOVERABLE COAL in relation to required production capability, it is apparent that the current RECOVERABLE COAL for both subbituminous and lignite coals are sufficiently large to support the supply system for the next 25 years even with greatly expanded demand. The major constraint will be developing increased production capability compatible with environmental requirements, land use conflicts, government policies, and financial requirements.

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Appendix A

Classification of Coals by Rank (ASTM)

Basis of Classification (Figure 2)

The rank classification outlined in Figure 2 is based on volatile matter, fixed carbon and heating value in Btu per pound. The higher-rank coals are classified according to fixed carbon on a dry, mineral-matter-free basis; the lower-rank coals are classified according to heating value on a moist, mineral-matter-free basis. Agglomerating character is used to differentiate between certain adjacent groups.

Classify coals having calorific values of 14 000 Btu/lb (32.6 MJ/kg) or more on the moist, mineral-matter-free basis and coals having fixed carbon of 69 per cent or more on the dry, mineral-matter-free basis, according to fixed carbon on the dry, mineral-matter-free basis; classify coals having calorific values less than 14 000 Btu/lb (32.6 MJ/kg) on the moist-mineral-matter-free basis according to calorific value on the moist, mineral-matter-free basis, provided the fixed carbon on the dry, mineral-matter-free basis is less than 69 per cent.

I Anthracitic Class — Nonagglomerating

Meta-anthracite (ma) - fixed carbon greater than or equal to 98 per cent; volatile matter equal or less than 2 per cent.

Anthracite (an) - fixed carbon less than 98 per cent and greater than or equal to 92 per cent; volatile matter greater than 2 per cent and equal or less than 8 per cent.

Semianthracite (sa) - fixed carbon less than 92 per cent, and greater than or equal to 86 per cent; volatile matter greater than 8 per cent and equal or less than 14 per cent; if agglomerating classify as low volatile.

II Bituminous Class — Commonly Agglomerating

Low volatile bituminous (lvb) - fixed carbon less than 86 per cent, and greater than or equal to 78 per cent; volatile matter greater than 14 per cent and equal or less than 22 per cent.

Medium volatile bituminous (mvb) - fixed carbon less than 78 per cent, and greater than or equal to 69 per cent; volatile matter greater than 22 per cent and equal or less than 31 per cent.

High volatile A bituminous (hvAb) - fixed carbon less than 69 per cent; volatile matter greater than 31 per cent; heating value greater than or equal to 14 000 Btu per pound (32.6 MJ/kg).

High volatile B bituminous (hvBb) - heating value less than 14 000 Btu per pound (32.6 MJ/kg), and greater than or equal to 13 000 Btu per pound (30.2 MJ/kg).

High volatile C bituminous (hvCb) - heating value less than 13 000 Btu per pound (30.2 MJ/kg), and greater than or equal to 11 500 Btu per pound (26.7 MJ/kg).

III Subbituminous Class — Nonagglomerating

Subbituminous A (subA) - heating value less than 11 500 Btu per pound (26.7 MJ/kg), and greater than or equal to 10 500 Btu per pound (24.4 MJ/kg); if agglomerating classify as high volatile C bituminous.

Subbituminous B (subB) - heating value less than 10 500 Btu per pound (24.4 MJ/kg), and greater than or equal to 9 500 Btu per pound (22.1 MJ/kg).

Subbituminous C (subC) - heating value less than 9 500 Btu per pound (22.1 MJ/kg), and greater than 8 300 Btu per pound (19.3 MJ/kg).

IV Lignitic Class — Nonagglomerating

Lignite A (ligA) - heating value less than 8 300 Btu per pound (19.3 MJ/kg), and greater than or equal to 6 300 Btu per pound (14.7 MJ/kg).

Lignite B (ligB) - heating value less than 6 300 Btu per pound (14.7 MJ/kg).

Appendix B

Resource Classification

A meaningful reporting of Canada's coal resources must be made in the context of a classification scheme that takes into account the great diversity of the nation's coal deposits. The coal resource classification scheme used in this report (Figure 6) classifies the resources according to two basic considerations: (1) the assurance of their existence and (2) the feasibility of exploitation. Each of these considerations is subdivided into categories having defined parameters. The definitions of terms and parameters used in this scheme are given below. They are somewhat similar to those used in the United States (Averitt, 1969) but are modified to suit local conditions that are present in the Canadian coal deposits.

Definition of Resource Terms

Coal Resources

The term "coal resources" for purposes of this report is defined as the coal that is contained in seams occurring within specified limits of thickness and depth from surface.

Assurance of Existence

The terms "measured", "indicated", "inferred" and "speculative" denote the level of confidence with which given quantities of resources have been determined or estimated; they are defined as follows:

Measured Resources are resources for which tonnages are computed from information revealed in outcrops, trenches, mine workings and boreholes. The spacing of points of observation necessary to justify confidence in the character and continuity of coal seams differs from region to region according to the character of the deposits and the geological conditions. In general the points of observation should be separated by less than the following distances:

Coal regions in Canada	Maximum distance between points of observation
	(in metres)
Cordillera*	300
(150 m in severely contorted areas)	
Plains	
Alberta	800
Saskatchewan	800
New Brunswick	400
Nova Scotia	
Sydney Coalfield, offshore	
Harbour and Phalen seams	1 600
Other seams	800
Sydney Coalfield, onshore	800
Other coalfields	300

Indicated Resources are resources for which tonnages are computed partly from specific measurements and partly from reasonable geological projections. For the general coal regions in Canada, the points of observation should be separated by less than the following distances:

Coal regions in Canada	Maximum distance between points of observation
	(in metres)
Cordillera	600
(300 m in severely contorted areas)	
Plains	
Alberta	1 600
Saskatchewan	1 600
New Brunswick	800
Nova Scotia	
Sydney Coalfield, offshore	
Harbour and Phalen seams	4 800
Other seams	1 600
Sydney Coalfield, onshore	1 600
Other coalfields	600

* Cordillera region includes all British Columbia and the Foothills and Mountain regions of Alberta.

Inferred Resources are resources for which quantity estimates are based largely on broad knowledge of the geologic character of the bed or region and for which few measurements of seam thickness are available. The estimates are based primarily on an assumed continuity of coal seams in areas remote from the points of observation used to calculate measured or indicated resources.

Speculative Resources are resources for which quantity estimates are based on information from a few scattered occurrences. Resources of this description are mainly in frontier areas where coal mining or exploration have not taken place.

Future Considerations

It is realized that it would be more meaningful to express the assurance of existence (level of confidence) by a range of possible error rather than by an arbitrary spacing of the points of observation. As an example, a measured resource estimate might be stated to have a level of confidence to within plus or minus 10 per cent. To achieve this requires complex analysis. It is intended to proceed with the work so that ultimately the coal resource will be reported in this manner.

Feasibility of Exploitation

Resources of Immediate Interest consist of coal seams that, because of favourable combinations of thickness, quality, depth, and location, are considered to be of immediate interest for exploration or exploitation activities. The conditions set out below do not apply rigorously in each case, but they give a general indication of thickness and depth of coal seams included in this category. In all areas, coal beds are included that are thinner or deeper than listed below but are nonetheless being mined at this time.

Cordillera:	Coal of all ranks in beds at least 1.5 m thick that can be surface-mined.
	Anthracitic and bituminous coal seams at least 1.5 m thick to a depth of 300 m, that are too deep for surface mining but might be mined underground.
Plains: (Alberta and Saskatchewan)	Bituminous and subbituminous coal beds at least 1.5 m thick to a depth of 230 m. Lignite seams at least 1.5 m thick that can be surface mined (generally to depths less than 45 m).
New Brunswick:	Seams at least 0.4 m to a depth of 24 m.
Nova Scotia:	
Offshore:	Seams at least one metre thick to a depth of 1 200 m.
Onshore:	Seams at least 0.5 m thick to depths of 45 m and all seams at least one metre thick to depth of 1 200 m.

Resources of Future Interest consist of coal seams that, because of less favourable combinations of thickness, quality, depth, and location, are not of immediate interest but may become of interest in the foreseeable future. The following limits are applied (excluding the resources of immediate interest described above):

Cordillera:	Seams at least 1.5 m thick to depths of 750 m.
Plains: (Alberta and Saskatchewan)	Seams at least one metre thick to depths of 450 m.
Nova Scotia:	
Offshore:	Seams at least one metre thick with depths in excess of 1 200 m.
Onshore:	Seams at least one metre thick with depths in excess of 1 200 m.

Future Considerations

When new mining technologies and/or changing economic conditions have indicated the possibility of mining thinner or deeper seams, or seams that are otherwise currently excluded from the estimates, it may become necessary to change the parameters for determining the feasibility of exploitation so as to include these coals in the estimates.

Appendix C

Reserve Classification

The reserve levels have been chosen to parallel the evolution of a coal prospect into an operating mine. Marketing considerations are excluded -- i.e. infinite markets at current prices are assumed. The flow chart (Figure 3) illustrates the path from a RESOURCE to a SALEABLE product; listing the limiting criteria, and subsequent coal deletions between various LEVELS. The measured Resources of Immediate Interest must be established within a coal deposit before reserves, at any LEVEL, can be determined.

<u>MINEABLE COAL</u> (LEVEL 1) is that part of the measured and indicated resources of immediate interest within a coal deposit, that can be considered for mining using current technology, and applying broad economic judgment only to the mining method.

<u>RECOVERABLE COAL</u> (LEVEL 2) is that part of MINEABLE COAL (Level 1) that could be recovered as run-of-mine coal with current technology and at current market prices. The coal deposit must be legally open to mining, and the necessary infrastructure must be in place or could be amortized through coal sales.

<u>CLEAN COAL</u> (LEVEL 3) is that portion of the RECOVERABLE COAL (Level 2) that would remain after required preparation.

<u>SALEABLE COAL</u> (LEVEL 4) is that coal deliverable to the end-user or "free on board". It represents CLEAN COAL (Level 3) plus any run-of-mine coal for sale where a preparation plant is required, and RECOVERABLE COAL (Level 2) where no preparation is planned.