A PETROGRAPHIC ATLAS OF CANADIAN COAL MACERALS AND DISPERSED ORGANIC MATTER

CANADIAN SOCIETY FOR COAL SCIENCE AND ORGANIC PETROLOGY

GEOLOGICAL SURVEY OF CANADA (CALGARY)

CANMET ENERGY TECHNOLOGY CENTRE

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Catalogue No. M40-58/1998E
ISBN 0-660-17538-X

Available in Canada from

Geological Survey of Canada (Calgary) Bookstore
3303-33rd Street N.W.
Calgary, Alberta T2L 2A7

A deposit copy of this publication is also available for
reference in selected public libraries across Canada

Price subject to change without notice

Cover Photo

Composite digital image of Tertiary *Botryococcus* alginite taken with confocal laser scanning microscope

FOREWORD

The Canadian Society for Coal Science and Organic Petrology has produced this atlas to celebrate twenty-five years of collaboration between coal geoscientists from the federal and provincial governments, universities and the coal and petroleum exploration industries in Canada.

The Society (CSCOP) evolved from the Canadian Coal Petrographers Group, which held its first meeting at CANMET's Bells Corners Research Laboratories in February, 1971. Originally formed to facilitate discussion between coal petrographers working in government and industry in the heyday of coal petrography and carbonization research, the Society has grown and embraced many new and applied aspects of coal petrography. As the coal and petroleum exploration industries developed and flourished in Canada, the fundamental concepts and methods used in coal petrography have been applied to coal carbonization, gasification and liquefaction; co-processing of coals and heavy oils; coalbed methane exploration; environmental petrography and geochemistry; bitumen and heavy oils; petroleum source rocks; and maturation studies. During the course of this evolution, a significant number of CSCOP members have been honoured nationally and internationally for their work.

We dedicate this Atlas to the founding members of our society[1], to past and present members, and to those who have worked and those who are still working in the fields of pure and applied coal and organic petrology. We hope it will be enjoyed and appreciated by new and former students of petrography everywhere.

Judith Potter
Editor

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1 See appendix for a brief history of the Society and members list

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ACKNOWLEDGEMENTS

The Society is extremely grateful to the following individuals who have contributed their time and talents towards the completion of this Atlas:

R. Marc Bustin, University of British Columbia, past President of the Canadian Coal Petrographers Group (1986), whose original idea of a Glossary of Canadian Coal Petrology eventually led to the compilation of this volume

Grant G. Smith, Geological Survey of Canada (Calgary), who kindly gave permission to reprint and modify the index maps and stratigraphic sections originally published in *Coal Resources in Canada,* GSC Paper 89-4

Grant Mossop, Geological Survey of Canada (Calgary), for permitting the compilation and reproduction of this volume using the facilities and expertise of many of the staff at the Geological Survey of Canada (Calgary), and for permission to reprint Figure 2

Bryan Rutley, Photography Lab, Geological Survey of Canada (Calgary), for reproducing many of the photomicrographs contained herein

Bryan Ortman, Geological Survey of Canada (Calgary), for invaluable assistance in compiling and producing this volume

Elizabeth Macey, Geological Survey of Canada (Calgary), for technical assistance with text, maps and figures

Michelle Hawke, University of British Cloumbia, for technical assistance with maps and figures

J. David Hughes, Geological Survey of Canada (Calgary), for assistance with coal resource information

Claudia Thompson, Geological Survey of Canada (Calgary), for assistance with text compilation

Jenny Wong, Geological Survey of Canada (Calgary), for confocal laser scanning microscopy

Glen Edwards, Geological Survey of Canada (Calgary), for image processing

John Bedbrook and staff, Precision Colour Imaging Ltd., Calgary, for digital imaging services

Ken Hampel, CANMET, Natural Resources Canada, for supplying coke samples

Sharlene Pollock, University of Calgary, for technical assistance with plates

Maria Tomica, Geological Survey of Canada (Calgary), for polishing and repolishing many pellets

Peter Giles, Geological Survey of Canada (Atlantic), for sample and stratigraphic information

Willem Langenburg, Alberta Geological Survey, for sample and stratigraphic information

Rob Naylor, Nova Scotia Department of Natural Resources, for sample and stratigraphic information

Clint St. Peter, New Brunswick Department of Natural Resources, for sample and stratigraphic information

Working Group Coordinators. The following people deserve special thanks for the considerable amount of time and effort they have contributed to this work:

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Editing. The efforts of all the contributors and technical assistants are gratefully acknowledged but CSCOP is especially grateful to J. Potter, L.D. Stasiuk and A.R. Cameron for invaluable contributions of their time, and technical and petrographic expertise. Elizabeth Macey, Joanna Monro Gray and John Utting, Geological Survey of Canada (Calgary) are thanked for editing the manuscript.

Reviews. Several members are thanked for reviewing portions of the manuscript:

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INTRODUCTION

The *Atlas of Canadian Coal Macerals and Dispersed Organic Matter* is a collection of photomicrographs of macerals found in coals and petroleum source rocks of potential and demonstrated importance in Canada. A reference list and a series of geographic and stratigraphic index maps accompanies each section of the Atlas to familiarize the user with the sources of the samples.

CANADIAN COALS

Coal accounts for 80% of Canada's fossil fuel energy resources. Deposits occur in almost every province in Canada: from Nova Scotia to British Columbia, and from the Canada–U.S.A. border to the Arctic Islands of northern Canada (Figure 1).

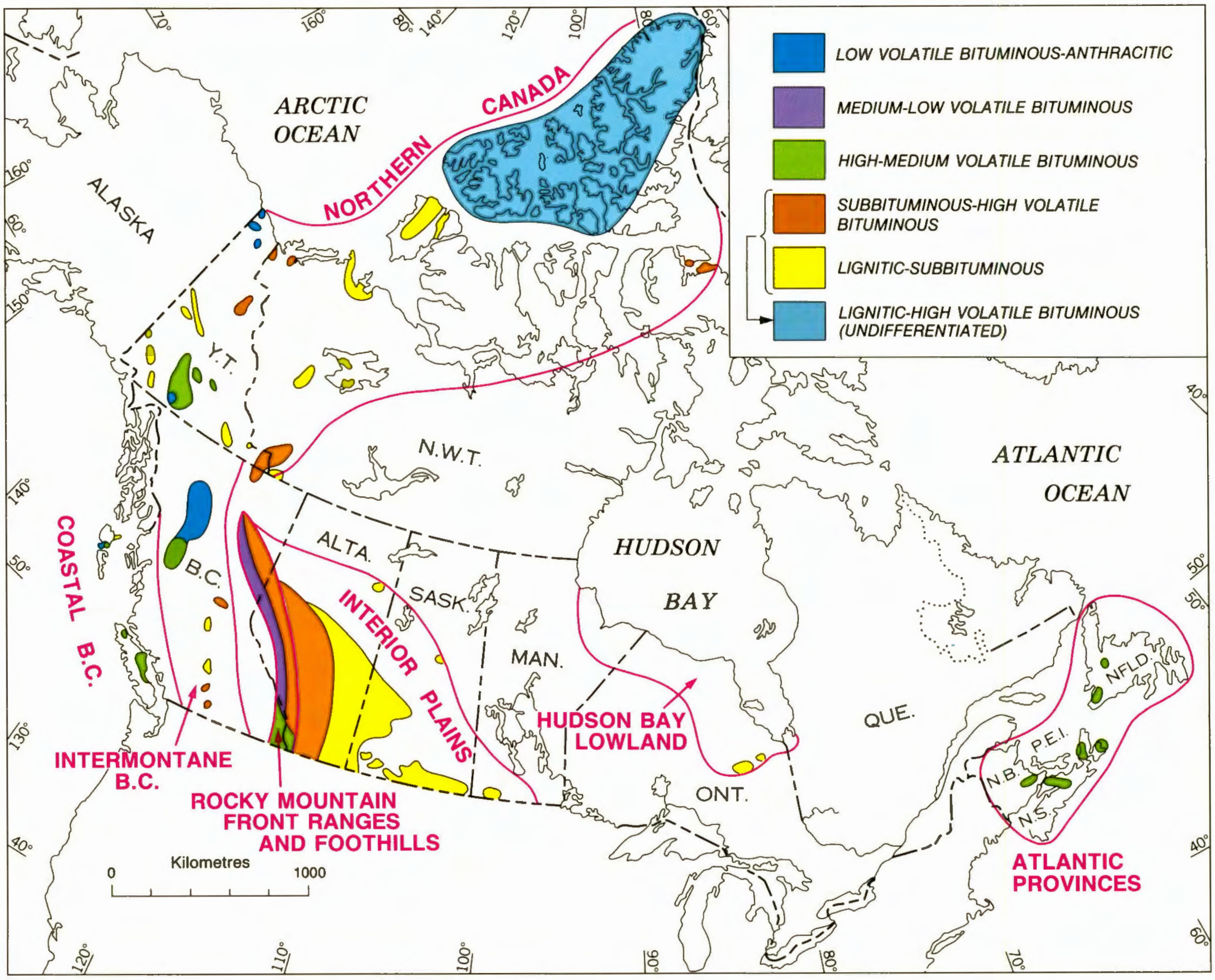

Figure 1. Distribution of coal in Canada

Canadian coals vary in rank, from lignites to anthracites, and in age from Late Devonian to Eocene. While a significant proportion of Canada's coal resources remains largely undeveloped, coal has been mined in eastern Canada since the 1700s, and in the west since the late 1800s. Currently, the most important coal-producing regions are British Columbia, Alberta, Saskatchewan and Nova Scotia. Coal production in Canada peaked in 1996, making Canada the world's eleventh largest coal producer (Coal Association of Canada, 1966). Currently, 19% of Canada's current domestic energy needs are met by coal, mostly for thermal-steam power generation. This is expected to rise to 23% by 2015 because of a decline in the use of nuclear power (Hughes, 1997). Metallurgical coke production is another important aspect of the coal industry in Canada and, while numerous deposits have been proven to contain coal suitable for liquefaction and gasification, there are significant coal resources at depth with demonstrated coalbed methane potential (Dawson, 1995). Approximately 34% of Canada's total coal production is exported as thermal and coking coal. A comprehensive account of Canada's coal resources, their geographic and geologic distribution and their quality and usage, is provided from a regional perspective by Smith (1989).

This atlas is intended to augment our current knowledge of Canada's coal deposits with details of the microscopic composition of the coals in relation to their rank. We have chosen to do this using a series of plates containing reflected light photomicrographs of coal macerals and mineral constituents as well as carbonization products from Canadian coals and coal blends. The Atlas seeks to represent the typical composition of Canadian coals in terms of macerals and minerals, as well as to document some of the less commonly occurring constituents, so that it can be viewed as a compendium of Canadian coal constituents. It has been designed as a practical handbook for coal petrographers and students of petrography. Since coal petrography has a substantive foundation that dates back to the 1950s, it is not our intention to revisit basic petrographic techniques and concepts in this publication. For a general background to basic principles and methods used in coal petrography, refer to Stach *et al.* (1992) and Bustin *et al.* (1983) and the various publications of the International Committee for Coal and Organic Petrology (see references, this section).

COAL MACERALS

The first part of the Atlas is devoted to coal macerals and minerals and is divided into the following sections, according to coal rank: lignites and subbituminous coals, high volatile bituminous coals, medium volatile bituminous coals, low volatile bituminous coals, semianthracites and anthracites. A section on carbonization residues from some Canadian coking coals is also included. Since it is important that the coals and their constituents be viewed within the context of a geologic framework in order to appreciate the variability and complexity of Canada's coal deposits, the caption of each plate contains the location of samples by coalfield and region and detailed stratigraphic references; i.e., age, seam and coal-bearing formation. In order to facilitate cross-referencing of this information, each section contains a collection of index maps and figures illustrating the geographic and stratigraphic points of reference for each coal sample. These figures are reproduced and modified, with the author's permission, from Smith (1989).

The coal rank classification used in this volume is that of ASTM Method D388-92, (ASTM, 1992; see Table 1). In most cases samples were analyzed chemically but in all cases ASTM classes have been related to reflectance measurements according to the thresholds suggested by Teichmüller and Teichmüller (1982). The reflectance data are expressed as maximum ($R_o m$) or random reflectance ($R_o r$), in oil, of the vitrinite (or huminite in low rank coals) according to internationally standardized procedures outlined by the International Committee for Coal and Organic Petrology (ICCP). Coal maceral terminology also follows definitions set by the International Committee for Coal and Organic Petrology. The maceral classification used for the lignites and subbituminous coals in this volume is that of the ICCP for lignites and brown coals (ICCP, 1971). For the high, medium and low volatile bituminous coals and anthracites, the ICCP classification of inertinite and liptinite macerals (ICCP, 1963, 1975) is used in conjuction with the most up-to-date classification of vitrinite and inertinite macerals (ICCP, 1995, 1997). The maceral nomenclature used for the low and high rank coals is summarized in Table 2; and to facilitate correlation between the new and old classifications, a comparison of the previously used vitrinite terminology and the new classification is shown in Table 3.

MATURATION AND RANK		MICROSCOPIC MATURITY PARAMETERS							ZONES OF HC GENERATION
STAGES OF MATURATION	COAL RANK	VITRINITE REFLECTANCE[1] (%R_o)	THERMAL ALTERATION INDEX (TAI): TAI[2]	THERMAL ALTERATION INDEX (TAI): TAI[3]	CONODONT ALTERATION INDEX (CAI)	FLUORESCENCE: COLOUR OF ALGINITE[4]	FLUORESCENCE: COLOUR OF SPORINITE[5]	SOLID BITUMEN REFLECTANCE (%R_o)	
DIAGENESIS	PEAT	0.2	1 YELLOW	1.5	1 YELLOW	GREENISH YELLOW	BLUE-GREEN		BIOGENIC METHANE, HEAVY OIL AND EARLY CONDENSATE
DIAGENESIS	LIGNITE	0.3	1 YELLOW		1 YELLOW	GREENISH YELLOW	BLUE-GREEN		BIOGENIC METHANE, HEAVY OIL AND EARLY CONDENSATE
DIAGENESIS / CATAGENESIS	SUB-BITUMIN. C, B, A	0.4, 0.5	1 YELLOW / 2 ORANGE	2.3, 2.5	1 YELLOW	GOLDEN YELLOW	GREEN, YELLOW	0.2	OIL, WET GAS AND CONDENSATE; OIL WINDOW
CATAGENESIS	HIGH VOLATILE BITUMINOUS C, B, A	0.6, 0.7, 0.8, 0.9	2 ORANGE	2.8	1 YELLOW / 2 LIGHT BROWN	GOLDEN YELLOW, DULL YELLOW	ORANGE	0.5	OIL, WET GAS AND CONDENSATE; OIL WINDOW
CATAGENESIS	MEDIUM VOLATILE BITUMINOUS	1.0, 1.2, 1.35	2 ORANGE / 3 BROWN	3.0	2 LIGHT BROWN	ORANGE, RED	BROWN	1.0, 1.5	OIL, WET GAS AND CONDENSATE; START OF MAJOR THERMOGENIC GAS GENERATION
CATAGENESIS	LOW VOLATILE BITUMINOUS	1.5	3 BROWN	3.5	3 BROWN	non-fluorescent		1.75, 2.0	WET GAS, DRY GAS; START OF MAJOR THERMOGENIC GAS GENERATION
METAGENESIS	SEMI-ANTHRACITE	2.0	3 BROWN / 4 BLACK	3.7	3 BROWN	non-fluorescent		2.5	WET GAS, DRY GAS; START OF MAJOR THERMOGENIC GAS GENERATION
METAGENESIS	ANTHRACITE	2.5, 3.0, 4.0	4 BLACK / 5 BLACK	4.0	4 DARK BROWN	non-fluorescent			DRY GAS
META-MORPH-OSIS	META-ANTHRACITE	5.0	5 BLACK		5 BLACK	non-fluorescent			DRY GAS

[1]from Teichmüller and Teichmüller (1982)
[2]from Staplin (1969)
[3]from Jones and Edison (1978)
[4]from Mukhopadhyay and Rullkötter (1986)

Table 1. Coal rank classes (ASTM, 1992) and equivalent petrographic maturity parameters, modified from Mukhopadhyay (1993)

LIGNITES AND SUBBITUMINOUS COALS			BITUMINOUS COALS AND ANTHRACITES		
Maceral Group	Maceral Subgroup	Maceral	Maceral	Maceral Subgroup	Maceral Group
HUMINITE[1]	humotelinite	textinite	telinite	telovitrinite	VITRINITE[2]
		ulminite	collotelinite		
	humodetrinite	attrinite	vitrodetrinite	detrovitrinite	
		densinite	collodetrinite		
	humocollinite	corpohuminite	corpogelinite	gelovitrinite	
		gelinite	gelinite		
LIPTINITE		sporinite	sporinite		LIPTINITE
		cutinite	cutinite		
		resinite	resinite		
		alginite	alginite		
		liptodetrinite	liptodetrinite		
		suberinite			
		chlorophyllinite			
		exsudatinite			
		bituminite			
		fluorinite			
INERTINITE[3]		micrinite	micrinite		INERTINITE[3]
		macrinite	macrinite		
		semimacrinite	semimacrinite		
		fusinite	fusinite		
		semifusinite	semifusinite		
		secretinite	secretinite		
		funginite	funginite		
		inertodetrinite	inertodetrinite		

[1] huminite and liptinite classifications, after ICCP (1971)
[2] vitrinite classification, after ICCP (1994)
[3] inertinite classification, after ICCP (1963, 1971, 1975, 1997)

Table 2. Classification of coal macerals

<table>
<tr><th colspan="2">VITRINITE GROUP (ICCP, 1982)</th><th colspan="2">VITRINITE GROUP (ICCP, 1994)</th></tr>
<tr><td>Maceral</td><td>Submaceral</td><td>Maceral</td><td>Maceral subgroup</td></tr>
<tr><td>Telinite</td><td>Telinite 1
Telinite 2</td><td>Telinite</td><td rowspan="2">Telovitrinite</td></tr>
<tr><td rowspan="5">Collinite</td><td>Telocollinite</td><td>Collotelinite</td></tr>
<tr><td>Desmocollinite</td><td>Collodetrinite</td><td rowspan="2">Detrovitrinite</td></tr>
<tr><td></td><td>Vitrodetrinite</td></tr>
<tr><td>Corpocollinite</td><td>Corpogelinite</td><td rowspan="2">Gelovitrinite</td></tr>
<tr><td>Gelocollinite</td><td>Gelinite</td></tr>
<tr><td>Vitrodetrinite[1]</td><td></td><td></td><td></td></tr>
</table>

[1]Vitrodetrinite is incorporated in the detrovitrinite subgroup (ICCP, 1994)

Table 3. A comparison of current and revised vitrinite classifications; after ICCP (1975, 1994)

DISPERSED ORGANIC MATTER AND BITUMEN

The second part of the Atlas is dedicated to dispersed organic matter (DOM) in petroleum source rocks from producing and prospective basins in Canada. Organic-rich carbonate and siliciclastic sedimentary rocks are an important part of the economic geology of Canada in that they provide the organic source material for the oil and gas and tar sand deposits in Canadian sedimentary basins (Figure 2). Examples of organic matter from potential hydrocarbon source rocks in most of the Canadian basins (Snowdon and Fowler, 1997) and oil shale deposits (Macauley *et al.*, 1985) are represented herein; they range in age from Early Cambrian to Early Tertiary and have been the source of significant, exploitable oil and gas accumulations found in almost all of the Canadian provinces and territories. The characteristic optical properties of the insoluble kerogen, DOM or macerals in organic-rich sediments, determined with the reflected light microscope, provide fundamental information about the type of petroleum the dispersed organic matter could potentially generate (Teichmüller and Ottenjann, 1977; Sentfle *et al.*, 1996), the stage of thermal diagenesis of the host sedimentary strata in relation to oil and gas generation (Tissot and Welte, 1984; Teichmüller, 1986), the organic facies, and the paleodepositional setting (Huc, 1990). Similarly, optical analysis of oily bitumens, solid bitumens and oil inclusions trapped within diagenetic minerals provides information relating to thermal maturity, and direct evidence for petroleum generation.

This section of the Atlas consists of a collection of reflected, white and fluorescent light photomicrographic plates of macerals and associated mineral components in organic-rich sedimentary rocks together with a few examples of bitumens from oil and gas reservoir rocks. The terminology used for classifying DOM is based on the coal maceral concept of the ICCP; the maceral group terms vitrinite, liptinite and inertinite are still used in the practical sense, but they fall within the broader genetic subdivisions of DOM: herbaceous, amorphous and alginite. Two additional categories, organic fossils and bitumens, are incorporated into the DOM classification to accommodate additional organic components commonly found in organic-rich carbonate and siliciclastic rocks (Table 4). The maceral variety category lists only the terms and examples used in the Atlas; it can be expanded to accommodate components not found in Canadian source rocks, as desired.

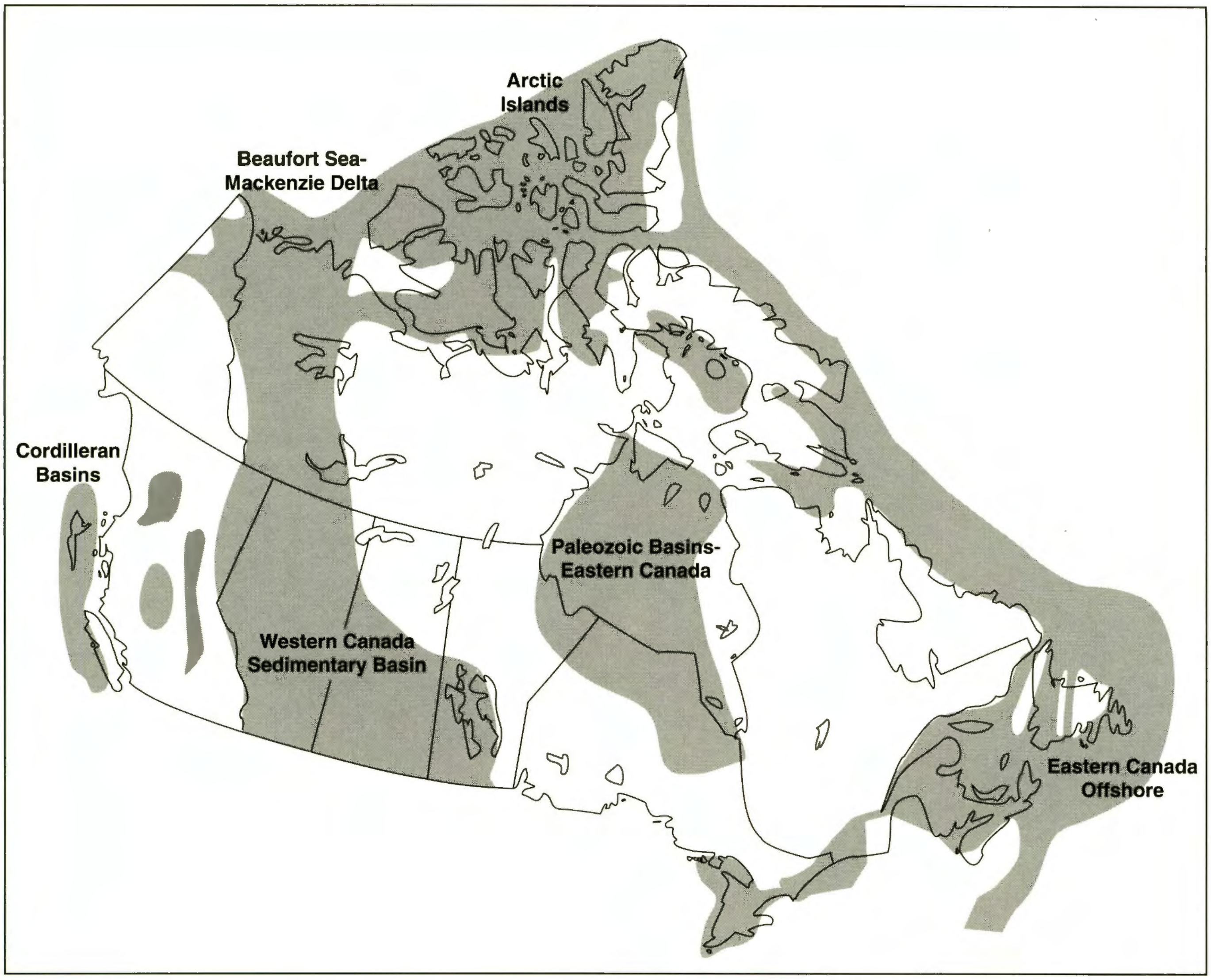

Figure 2. Distribution of major sedimentary basins, Canadian mainland and Arctic Archipelago

The photomicrographs shown in the Coal Maceral and Dispersed Organic Matter sections are of polished coal and whole rock samples and were photographed using white and fluorescent, incident/reflected light and oil and water immersion objectives. The magnification scales shown on each plate are consistent for all the individual photomicrographs, unless indicated otherwise in the caption, whereupon an alternative scale bar is shown directly on the photomicrograph.

Each section of the Atlas contains a set of key references. Reprints can be obtained by contacting individual members of the Society or the CSCOP Publications Editor, via the CSCOP Home page: www.cscop.org, or from the Geological Survey of Canada (Calgary) bookstore.

DOM (CSCOP Atlas)	MACERAL GROUP (after ICCP)	MACERAL	MACERAL VARIETY
Herbaceous	Huminite/Vitrinite[1]	see Table 2	phyllovitrinite
	Inertinite	see Table 2	
	Liptinite	sporinite	
		cutinite	
		resinite	
		suberinite	
		fluorinite	
		chlorophyllinite	
Amorphous		amorphinite[2]	hebamorphinite[2]
			fluoramorphinite[2]
			matrix bituminite[3]
Alginite		alginite[4]	*Botryococcus*
			Pila-Rheinshia
			Tasmanites
			Leiosphaeridia
			filamentous
			Gloeocapsomorpha
			dinoflagellates
		acritarchs	
Organic fossils	Zooclast[5]	scolecodont	
		graptolite	
		chitinozoan	
		foraminifera	
		conchostracan	
Bitumen	Bitumen[6]	exsudatinite	
		primary bitumen	
		migrabitumen	
		pyrobitumen	

[1]see Table 1 for vitrinite maceral classification
[2]after Sentfle et al. (1987); synonyms: bituminite, amorphous organic matter
[3]after Creaney (1980)
[4]after Stasiuk (1994)
[5]after Alpern (1980)
[6]after Jacob (1989)

Table 4. "Maceral" classification for primary dispersed organic matter (DOM) and bitumens

REFERENCES: INTRODUCTION

Alpern, B. (1980). Pétrographie du kérogène. In: Kerogen: Insoluble Organic Matter from Sedimentary Rocks, B. Durand (ed.). Éditions Technip, Paris: 339-384.

American Society for Testing and Materials (1992). Annual Book of ASTM Standards, Section 5, Petroleum products, Lubricants and Fossil Fuels, Method D388-92, 192-195.

Bustin, R.M., Cameron, A.R., Grieve, D.A. and Kalkreuth, W.D. (1983). Coal Petrology: Its Principles, Methods and Applications. Geological Association of Canada, Short Course Notes, V. 3, 230 p.

Coal Association of Canada (1996). Canadian Coal Statistics. 1996 data. Coal Association of Canada.

Creaney, S. (1980). The organic petrology of the upper Cretaceous Boundary Creek Formation, Beaufort-Mackenzie Basin. Bulletin of Canadian Petroleum Geology, V. 28: 112-129.

Dawson, F.M. (1995). Coalbed methane: A comparison between Canada and the United States, Geological Survey of Canada, Bulletin 489, 60 p.

Huc, A.Y. (1990). Understanding organic facies: A key to improved quantitative petroleum evaluation of sedimentary basins. In: Deposition of Organic Facies, A.Y. Huc (ed.). AAPG Studies in Geology No. 30, American Association Petroleum Geologists, Tulsa, U.S.A.

Hughes, J.D. (1997). National Coal and Environment Program Evaluation, Geological Survey of Canada.

International Committee for Coal Petrology (1963). Handbook of Coal Petrology, 1st Edition, Centre Nationale de la Recherche Scientifique, Paris.

International Committee for Coal Petrology (1971). Handbook of Coal Petrology, 2nd Edition, Centre Nationale de la Recherche Scientifique, Paris.

International Committee for Coal Petrology (1975). Handbook of Coal Petrology, supplement to 2nd Edition, Centre Nationale de la Recherche Scientifique, Paris.

International Committee for Coal Petrology (1995). Vitrinite Classification. ICCP System 1994. International Committee for Coal and Organic Petrology, Aachen, Germany, 1995.

International Committee for Coal Petrology (1997). Inertinite Classification. ICCP System 1997. International Committee for Coal and Organic Petrology, Wellington, New Zealand, 1997.

Jacob, H. (1989). Classification, structure, genesis and practical importance of natural solid bitumen ("migrabitumen"). International Journal of Coal Geology, V. 11: 65-69.

Jones, R.W. and Edison, T.A. (1978). Microscopic observation of kerogen related to geochemical paramenters with emphasis on thermal maturation. In: Low Temperature Metamorphism of Kerogen and Clay Minerals, D.F. Oltz (ed.). SEPM Special Publication, p. 1-12.

Macauley, G., Snowdon, L.R. and Ball, F.D. (1985). Geochemistry and geological factors governing exploitation of selected Canadian oil shale deposits. Geological Survey of Canada, Paper 85-13, 65 p.

Mukhopadhyay, P.K. (1994). Vitrinite reflectance as a maturity parameter: Petrographic and molecular characterization and its applications to basin modelling. In: Vitrinite Reflectance as a Maturity Parameter: Applications and Limitations, P.K. Mukhopadhyay and W.G. Dow (eds.). ACS Symposium Series 570, American Chemical Society, Washington D.C., p. 1-25.

Mukhopadhyay, P.K. and Rullkötter, J. (1986). Quantitative microscopic spectral fluorescence measurement of crude oil, bitumen, kerogen and coal. American Association Petroleum Geologists, Bulletin, V. 70: 624.

Sentfle, J., Brown, J.H. and Larter, S.R. (1987). Refinement of organic petrographic methods for kerogen characterization. International Journal of Coal Geology, V. 7: 105-117.

Sentfle, J.T., Landis, C.R. and McLaughlin, R. (1996). Organic petrographic approach to kerogen characterization. In: Organic Geochemistry: Principles and Applications, M.H. Engel and S.A. Macko (eds.). Plenum Press, New York, p. 355-396.

Smith, G.G. (1989). Coal Resources of Canada, Geological Survey of Canada, Paper 89-4, 146 p.

Snowdon, L.R. and Fowler, M.G. (1997). Interpretation of Geochemical Data. Short Course Notes, CSPG-SEPM Joint Convention, Calgary, Alberta, 1997, 96 p.

Stach E., Mackowsky, M.-Th., Teichmüller, M., Taylor, G.H., Chandra, D. and Teichmüller, R. (1982). Stach's Textbook of Coal Petrology. Gebrüder Borntraeger, Berlin, New York, 535 p.

Staplin, F.L. (1969). Sedimentary organic matter, organic metamorphism and oil and gas occurrence. Bulletin of Canadian Petroleum Geology, V. 17: 47-66.

Stasiuk, L.D. (1994). Oil-prone alginite macerals from organic-rich Mesozoic and Paleozoic strata, Saskatchewan, Canada. Marine and Petroleum Geology, V. 11: 208-218.

Teichmüller, M. (1986). Organic petrology of source rocks, history and state of the art. In: Advances in Organic Geochemistry, D. Leythauser and J. Rullkötter (eds.). 1985, V. 10: 581-599.

Teichmüller, M. and Ottenjann, K. (1977). Liptinites and lipoid substances in a petroleum source rock. Erdöl und Kohle, Erdgas, Petrochemie. Brenstoff Chemie, V. 30: 387-398.

Teichmüller, M. and Teichmüller, R. (1982). The geological basis of coal formation. In: Stach's Textbook of Coal Petrology, E. Stach, M.-Th. Mackowsky, M. Teichmüller, G.H. Taylor, D. Chandra and R. Teichmüller. Gebrüder Borntraeger, Berlin, 428 p.

Tissot, B.P. and Welte, D.H. (1984). Petroleum Formation and Occurrence. Springer-Verlag, New York, 699 p.

van Gijzel, P. (1981). Applications of the geomicrophotometry of kerogen, solid hydrocarbons and crude oils in petroleum exploration. In: Organic Maturation and Fossil Fuel Exploration, J. Brooks (ed.). Academic Press, New York, p. 351-378.

SECTION I COAL MACERALS

LIGNITES AND SUBBITUMINOUS COALS

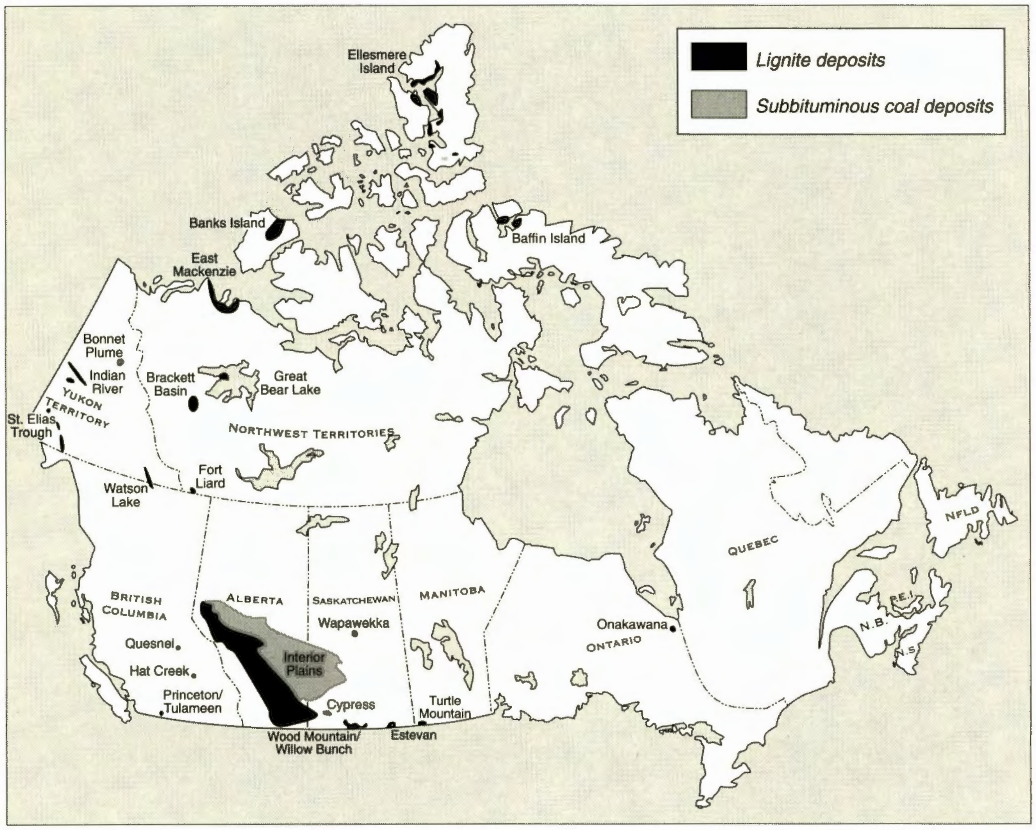

Figure 3a. Lignite and subbituminous coal deposits

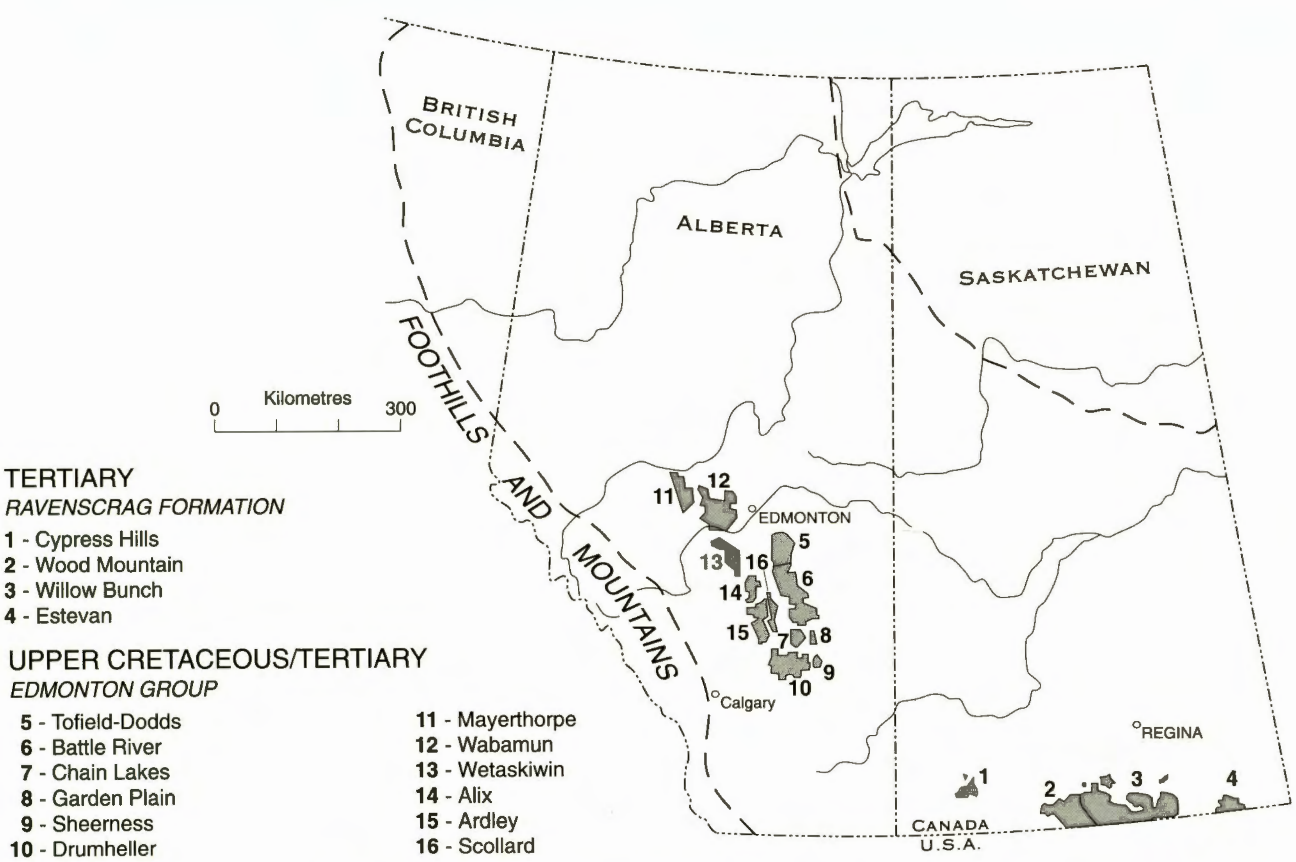

Figure 3b. Low rank coalfields of Western Canada

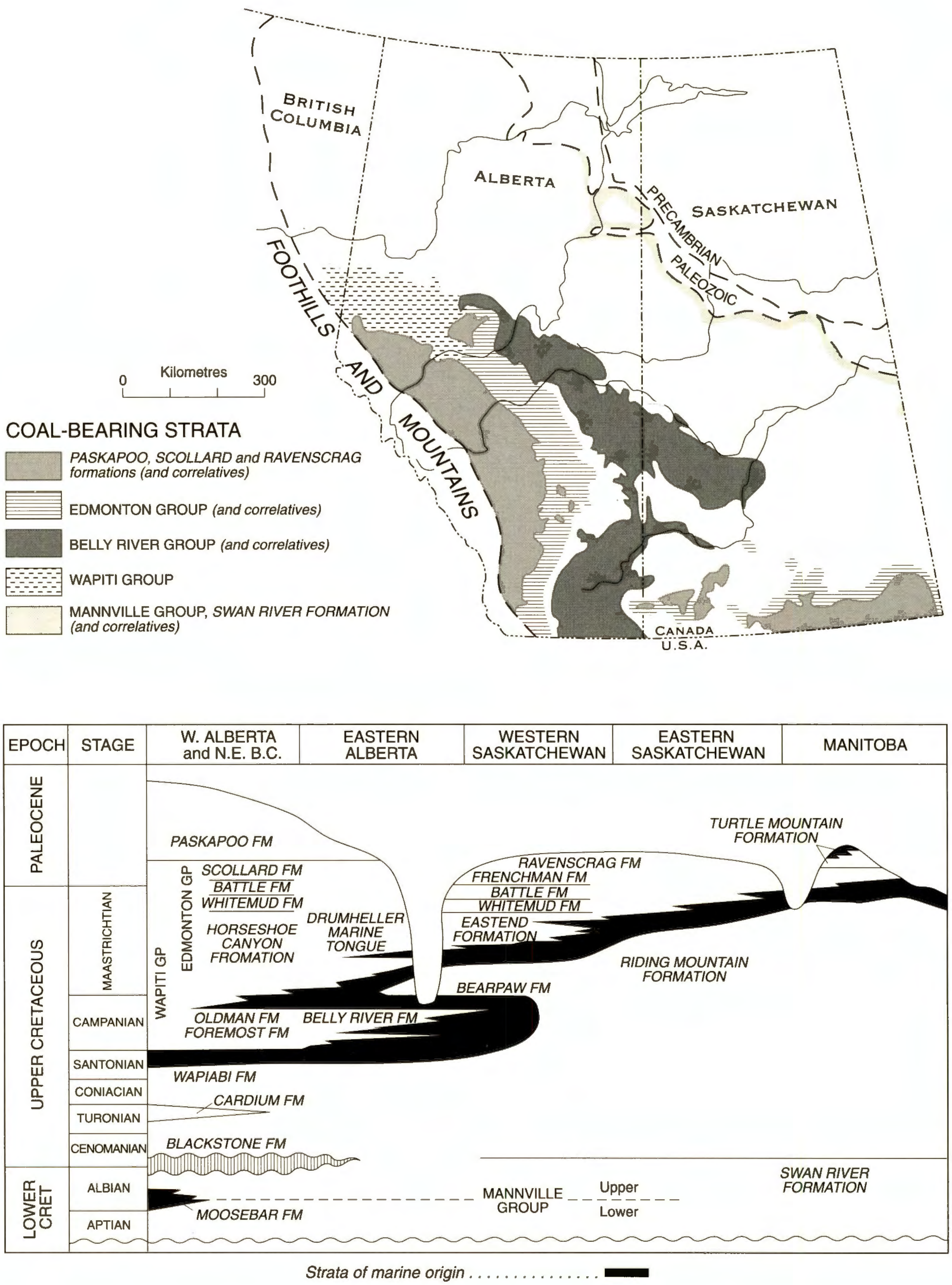

Figure 3c. Coal-bearing formations of Interior Plains region

PLATE 1

LIGNITES AND SUBBITUMINOUS COALS
HUMINITE: HUMOTELINITE MACERALS

All photomicrographs were taken using white incident light and oil immersion objectives,
except photo **n** which is a blue light image
aspect: L.T.S. = longitudinal tangential section; T.S. = transverse section
magnification: same for all photos; see scale bar in photo **p**
coal rank: $\%R_or$ = mean random reflectance, in oil, of eu-ulminite B

a. L.T.S. of **textinite** (T) and **texto-ulminite** (Tu) from angiosperm wood, showing ray cells, relatively ungelified cell walls with open cell lumens; Paleocene lignite (0.31$\%R_o$r), Hart Seam, Ravenscrag Formation, Willow Bunch Coalfield, south-central Saskatchewan

b. L.T.S. of **textinite** (T) grading to **texto-ulminite** (Tu) exhibiting a higher degree of cell wall gelification than in photo a, from conifer wood with ray cells; Paleocene lignite (0.36$\%R_o$r), Estevan Seam, Ravenscrag Formation, Estevan Coalfield, southeastern Saskatchewan

c. L.T.S of **eu-ulminite A** (UA) and **B** (UB) with minor **texto-ulminite B** (Tu), Eocene lignite-subbituminous coal (0.38-0.40$\%R_o$r), Hat Creek Formation, Hat Creek Coalfield, British Columbia

d. T.S. of **textinite** (T) and **texto-ulminite** (Tu) with semifusinite (Sf); Paleocene lignite (0.36$\%R_o$r), Estevan Seam, Ravenscrag Formation, Estevan Coalfield, southeastern Saskatchewan

e. T.S. of **texto-ulminite B** (Tu) with open cell lumina and extensively gelified cell walls; Eocene lignite-subbituminous coal (0.38-0.42$\%R_o$r), Hat Creek Formation, Hat Creek Coalfield, British Columbia

f. L.T.S. of **eu-ulminite B** derived from gelified and compacted, possibly mesophyll tissue; Paleocene lignite, (0.32$\%R_o$r), Summit Creek Formation, Brackett Basin, Northwest Territories

g. **eu-ulminite** derived from a variety of angiosperm ?leaf tissues including mesophyll (U-m) and palisade layer (U-p) with a thin, weakly reflective, external layer of cutinite (Cu); Paleocene lignite (0.31$\%R_o$r), Hart Seam, Ravenscrag Formation, Willow Bunch Coalfield, south-central Saskatchewan

h. L.T.S. of **eu-ulminite B** (UB) with relatively highly reflecting corpohuminite (Co) embedded in it; Paleocene lignite (0.28$\%R_o$r), Willow Bunch Seam, Ravenscrag Formation, Willow Bunch coalfield, south-central Saskatchewan

i. **eu-ulminite B** (UB) with well-preserved ray cells and elongate corpohuminite (Co) bodies; Paleocene lignite (0.28$\%R_o$r), Willow Bunch Seam, Ravenscrag Formation, Willow Bunch Coalfield, south-central Saskatchewan

j. L.T.S. of **eu-ulminite B** (UB) infilled by **eu-ulminite A** (UA) and inclusions of round corpohuminites (Co); Paleocene lignite (0.31$\%R_o$r), Hart Seam, Ravenscrag Formation, Willow Bunch Coalfield, south-central Saskatchewan

k. T.S. of **eu-ulminite B** (UB) from tracheid cells with **texto-ulminite A** (UA) from dark sclereid cells; Paleocene lignite (0.28$\%R_o$r), Willow Bunch Seam, Ravenscrag Formation, Willow Bunch Coalfield, south-central Saskatchewan

l. L.T.S. of **eu-ulminites A** and **B** (UA, UB) in light and dark bands dominated by the more highly-reflective ulminite B; Paleocene lignite (0.28$\%R_o$r), Willow Bunch Seam, Ravenscrag Formation, Willow Bunch Coalfield, south-central Saskatchewan

m. T.S. of **eu-ulminite B** (UB) derived from tracheid (sclerenchyma) cells and **eu-ulminite A** (UA) from dark sclereids embedded in it, Paleocene lignite (0.28$\%R_o$r), Willow Bunch Seam, Ravenscrag Formation, Willow Bunch Coalfield, south-central Saskatchewan

n. non-fluorescing **eu-ulminite B** (UB) with dark **eu-ulminite A** from sclereids (UA) showing relatively strong yellow fluorescence; Paleocene lignite (0.32$\%R_o$r) from Summit Creek Formation, Brackett Basin, Northwest Territories; blue light excitation

o. as **n**, white light image

p. concentric layers of **eu-ulminite A** (UA) and **B** (UB); Paleocene lignite (0.28$\%R_o$r), Willow Bunch Seam, Ravenscrag Formation, Willow Bunch Coalfield, south-central Saskatchewan

PLATE 1

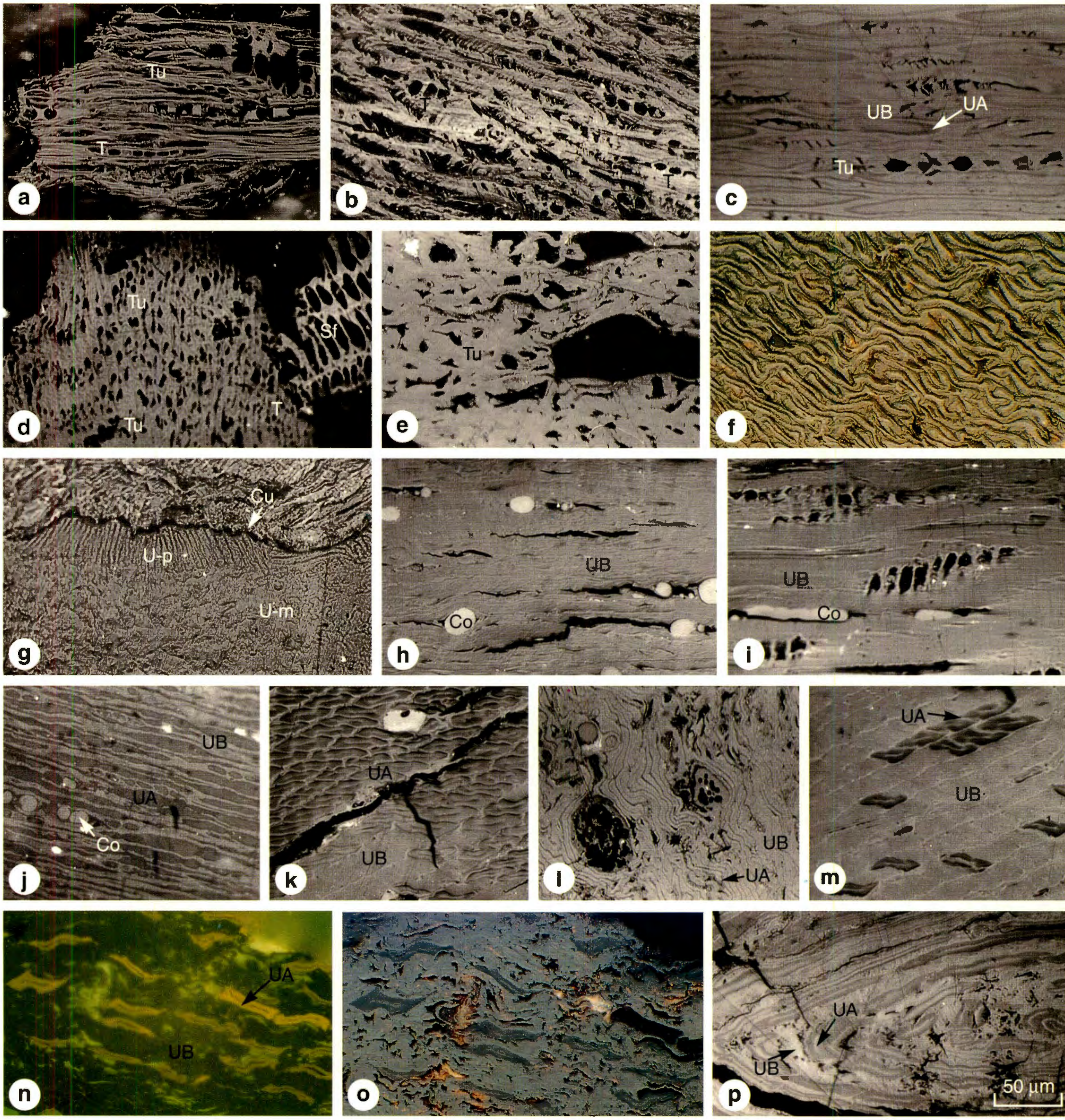

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PLATE 2

LIGNITES AND SUBBITUMINOUS COALS
HUMINITE: HUMODETRINITE MACERALS (a-f) and HUMOCOLLINITE MACERALS (g-p)

All photomicrographs were taken using white incident light and oil immersion objectives, except for photo **d**, which is a blue light image
magnification: same for all photos; see scale bar in photo **q**
coal rank: $\%R_or$ = mean random reflectance, in oil, of eu-ulminite B

a. **densinite** (D) - an aggregation of moderately well-gelified huminite detritus with small amounts of other macerals; Paleocene lignite ($0.32\%R_or$), Summit Creek Formation, Brackett Basin, Northwest Territories

b. **densinite** groundmass (D) with abundant fragmental inertodetrinite (Id) embedded in it; Paleocene lignite ($0.31\%R_or$), Hart Seam, Ravenscrag Formation, Willow Bunch Coalfield, south-central Saskatchewan

c. **densinite** groundmass (D) hosting dark liptinites (L) (var: resinite) and some inertinite fragments; Eocene lignite-subbituminous coal ($0.42\%R_or$), Hat Creek Formation, Hat Creek Coalfield, British Columbia

d. same field **(densinite)** as photo **a** but in fluorescence mode, showing low intensity fluorescence; blue light excitation; Paleocene lignite ($0.31\%R_or$), Summit Creek Formation, Brackett Basin, Northwest Territories

e. **densinite** (D) with a high proportion of inertodetrinite (Id) and **humocollinite** (Hc) and liptinite (L) (var: sporinite); in Eocene lignite-subbituminous coal ($0.42\%R_or$), Hat Creek Formation, Hat Creek Coalfield, British Columbia

f. **attrinite** (A), a loosely packed groundmass of relatively ungelified huminite detritus with some highly reflecting inertodetrinite dispersed throughout; in Paleocene lignite ($0.36\%R_or$), Estevan Seam, Ravenscrag Formation, Estevan Coalfield, southeastern Saskatchewan

g. **porigelinite** (Gp), a porous variety of gelinite, infilling vessels in angiosperm wood has significantly higher reflectance than the surrounding ulminite (U); Paleocene lignite ($0.31\%R_or$), Hart Seam, Ravenscrag Formation, Willow Bunch Coalfield, south-central Saskatchewan

h. **levigelinite** (Gl), a highly gelified and massive form of gelinite, showing significantly higher reflectance and relief than the associated huminite, and very susceptible to desiccation, as shown here by the extensive fracture network; Eocene lignite-subbituminous coal (0.42% R_or), Hat Creek Formation, Hat Creek Coalfield, British Columbia

i. bands of **gelinite macerals (var: levigelinite)** (Gl) interbedded with **densinite** (D); Eocene lignite-subbituminous coal ($0.42\%R_or$), Hat Creek Formation, Hat Creek Coalfield, British Columbia

j,m. spindle-shaped **corpohuminites (var: phlobaphenites)** (Co) infilling vessels in angiosperm wood showing significantly higher reflectance and relief than the associated huminite, which is typical of gelinite macerals; Eocene lignite-subbituminous coal ($0.42\%R_or$), Hat Creek Formation, Hat Creek, British Columbia

k. **corpohuminite (var: phlobaphenite)** (Co) infilling cork tissue in conifer wood rimmed by thin, weakly reflecting suberinite (Su); Eocene lignite-subbituminous coal ($0.42\%R_or$), Hat Creek Formation, Hat Creek, British Columbia

l. **corpohuminites** (Co) embedded in ulminite (U); Paleocene lignite ($0.34\%R_or$), Souris Seam, Ravenscrag Formation, Estevan Coalfield, southeastern Saskatchewan

n,o. **corpohuminites (var: phlobaphenite)** (Co) in humotelinite; Paleocene lignite ($0.27\%R_or$) from the Ferris Seam, Ravenscrag Formation, Cypress Coalfield, southwestern Saskatchewan (**n**) and the Paleocene Hart Seam, Willow Bunch Coalfield, south-central Saskatchewan (**o**)

p. **corpohuminite (var: phlobaphenite)** (Co) in rootlet (T.S.); Paleocene lignite ($0.32\%R_or$), Summit Creek Formation, Brackett Basin, Northwest Territories

q. highly reflective **corpohuminite (var: phlobaphenite)** (Co) infilling suberinite in cork/bark tissue; Paleocene lignite ($0.32\%R_or$), Summit Creek Formation, Brackett Basin, Northwest Territories

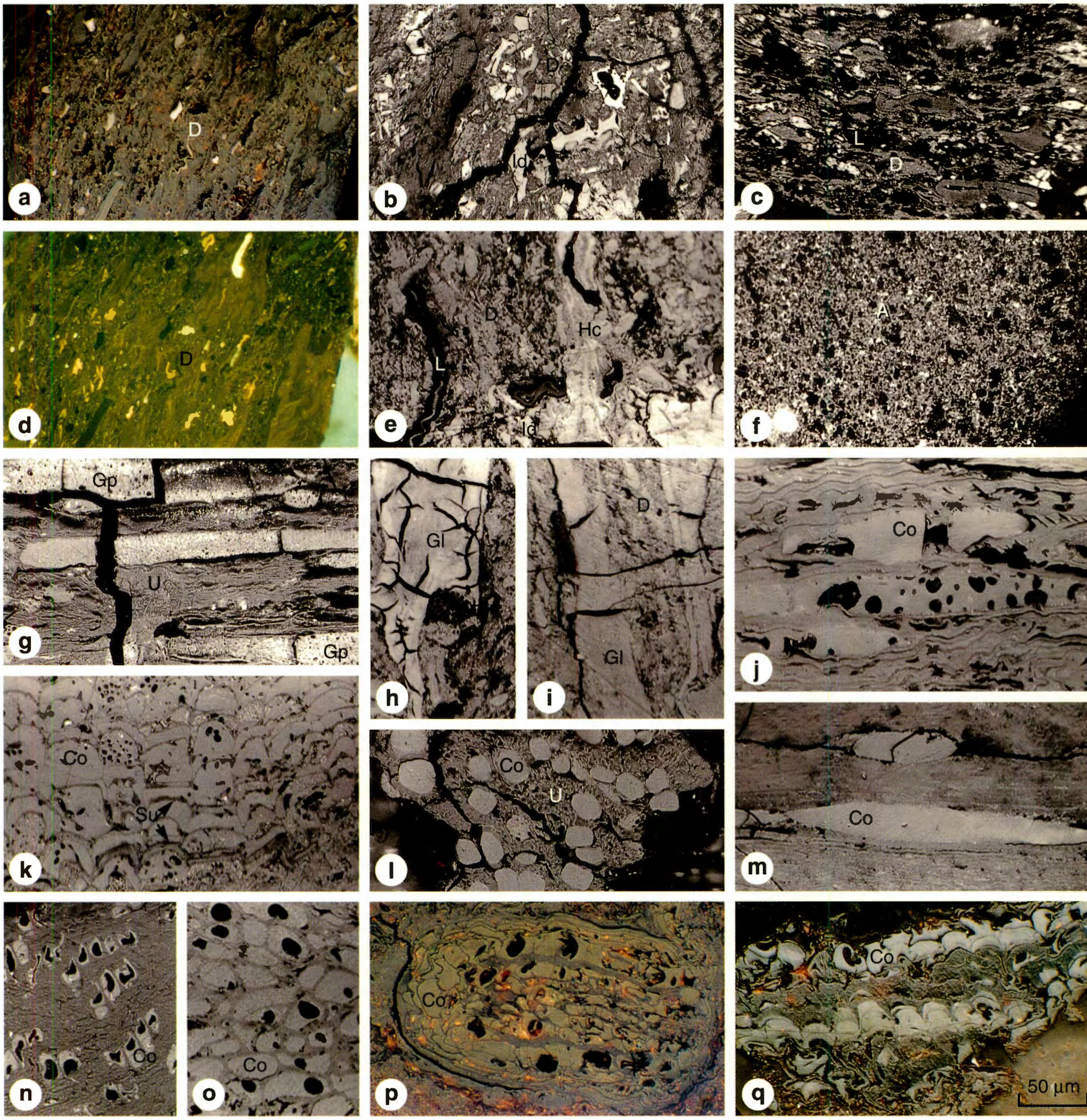
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PLATE 3

LIGNITES AND SUBBITUMINOUS COALS
LIPTINITE MACERALS

Photomicrographs **a**, **b**, **d**, **e**, **f**, **g**, **i**, **n**, **p**, **s**, **u**, **v**, **x** and **y** were taken using white incident light and oil immersion objectives; **c**, **h**, **j**, **k**, **l**, **m**, **o**, **q**, **r**, **t**, **w** and **z** were taken using blue incident light and oil immersion objectives
aspect: T.S. = transverse section; **magnification:** same for all photos; see scale bar in photo **z**
coal rank: %R_or = mean random reflectance, in oil, of eu-ulminite B

a. cork tissue composed of **suberinite** (Su) infilled with corpohuminite (var: phlobaphenite) (Co); Paleocene lignite (0.32%R_or) from Summit Creek Formation, Brackett Basin, Northwest Territories

b. dark, weakly reflecting **suberinite** (Su) derived from cork tissue with typical "lacy" habit, infilled by phlobaphenite; Paleocene lignite (0.33%R_or) from Summit Creek Formation, Brackett Basin, Northwest Territories

c. as **b**, highly fluorescent **suberinite** (Su) and weakly fluorescing corpohuminite (var:phlobaphenite) (Co) viewed in fluorescent light

d. T.S. of **suberinite** (Su) filled with corpohuminite (var:phlobaphenite) (Co); Eocene lignite (0.38%R_or) from Hat Creek deposit, British Columbia

e. densely packed **cutinite** (Cu) derived from thin ?leaf cuticles (var. tenuicutinite); Paleocene lignite (0.31%R_or), Hart Seam, Ravenscrag Formation, Willow Bunch Coalfield, south-central Saskatchewan

f. thick, weakly reflecting **cutinite?** (Cu) (var: crassicutinite) in ulminite (U), Paleocene lignite (0.27%R_or) from the Ferris Seam, Ravenscrag Formation, Cypress Coalfield, southwestern Saskatchewan

g. thin **cutinite** (Cu) with eu-ulminite (U) and densinite (D) and phlobaphenite (Co); Paleocene lignite (0.32%R_or) from the Summit Creek Formation, Brackett Basin, Northwest Territories

h. same field as **g**, fluorescent light; note the intense fluorescence of cutinite

i,j. thick **cutinite** (Cu) viewed in white (**i**) and fluorescent (**j**) light; Paleocene lignite (0.32%R_or), Summit Creek Formation, Brackett Basin, Northwest Territories

k. thick **cutinite** (Cu) viewed in fluorescent light; Upper Cretaceous subbituminous coal (0.42%R_or), Battle River Seam, Horseshoe Canyon Formation, Battle River Coalfield, southeastern Alberta

l. weakly fluorescing, oval **resinite** (R) bodies included in huminite (fluorescent light); Upper Cretaceous subbituminous coal (0.42%R_or), Battle River Seam, Horseshoe Canyon Formation, Battle River Coalfield, southeastern Alberta

m. highly fluorescing **resinite** (R); Upper Cretaceous subbituminous coal (0.42%R_or), Battle River Seam, Horseshoe Canyon Formation, Battle River Coalfield, southeastern Alberta

n. huminite (H) impregnated with **resinite** (R) showing negative surface relief; Paleocene lignite (0.31%R_or), Hart Seam, Ravenscrag Formation, Willow Bunch Coalfield, south-central Saskatchewan

o. as **n**, fluorescent light; note the weak fluorescence of the resinite

p. dark, weakly reflecting, **resinites** (R) in densinite groundmass (D) showing positive surface relief; Paleocene lignite (0.36%R_or), Estevan Seam, Ravenscrag Formation, Estevan Coalfield, southeastern Saskatchewan

q. strongly fluorescing **?fluorinite/resinite** (F); Upper Cretaceous subbituminous coal (0.42%R_or), Battle River Seam, Horseshoe Canyon Formation, Battle River Coalfield, southeastern Alberta

r. unidentified **liptinite** (Lp) possibly angiosperm drupe, fluorescence illumination; Paleocene lignite (0.32%R_or), Summit Creek Formation, Brackett Basin, Northwest Territories

s. same field as **r**, white light

t. **alginite** (A) from fresh water, coccoid algae (*Botryococcus*-type) in fluorescent light, showing high intensity but lighter yellow colours than sporinite (Sp) in z; Upper Cretaceous subbituminous coal (0.42%R_or), Battle River Seam, Horseshoe Canyon Formation, Battle River Coalfield, southeastern Alberta

u. as **t**, white light

v. **sporinite** (Sp) - thin-walled microspores (tenuisporinite) and liptodetrinite (Ld) embedded in densinite; Paleocene lignite (0.32%R_or), Summit Creek Formation, Brackett Basin, Northwest Territories

w. as **v**, fluorescence illumination

x. **sporinite** (Sp) - microspores densely packed into a sporangium; Paleocene lignite (0.28%R_or), Ravenscrag Formation, Willow Bunch Coalfield, south-central Saskatchewan

y. **sporinite** (Sp) - microspores in densinite; Eocene lignite (0.38%R_or), Hat Creek deposit, British Columbia

z. strongly fluorescing **sporinite** (microspores) (Sp); Upper Cretaceous subbituminous coal (0.42%R_or), Battle River Seam, Horseshoe Canyon Formation, Battle River Coalfield, southeastern Alberta

PLATE 3

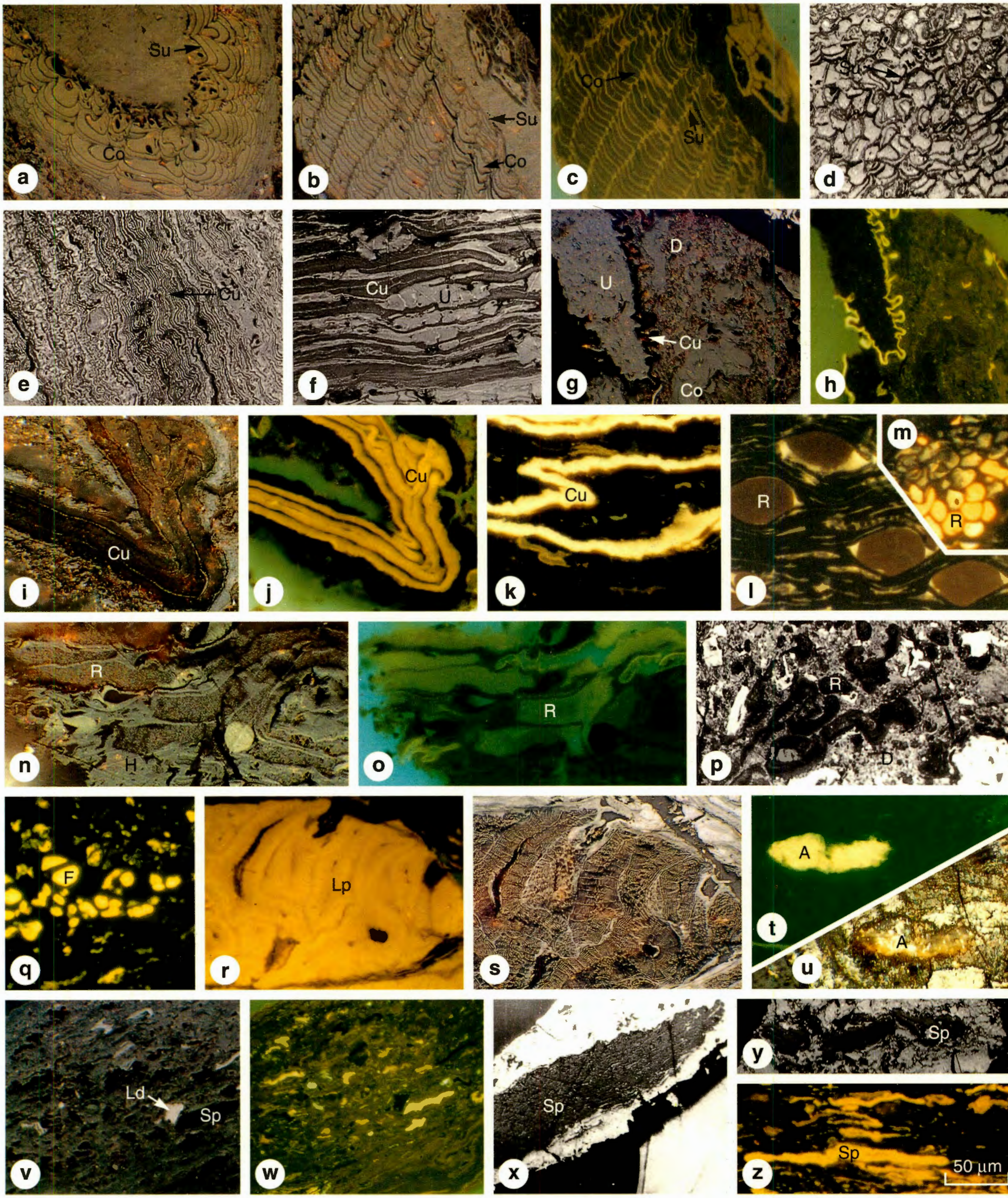

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PLATE 4

LIGNITES AND SUBBITUMINOUS COALS
INERTINITE MACERALS AND MINERAL MATTER

All photomicrographs were taken using white incident light and oil immersion objectives
aspect: L.T.S. = longitudinal tangential section; T.S. = transverse section
magnification: same for all photos; see scale bar in photo **w**
coal rank: %R_or = mean random reflectance, in oil, of eu-ulminite B

INERTINITE MACERALS

a. T.S. of **fusinite** derived from tracheids and rays of wood; Paleocene lignite (0.36%R_or), Willow Bunch Seam, Ravenscrag Formation, Willow Bunch Coalfield, south-central Saskatchewan

b,c. L.T.S. of **fusinite** (Fu) from wood tracheids and rays; Paleocene lignite (0.36%R_or), Willow Bunch Seam, Ravenscrag Formation, Willow Bunch Coalfield, south-central Saskatchewan

d. **semifusinite** (Sf) with **fusinite** (Fu); Paleocene lignite (0.31%R_or), Hart Seam, Ravenscrag Formation, Willow Bunch Coalfield, south-central Saskatchewan

e. **funginites** (Fg, arrows) from fungal sclerotia and spores; Eocene lignite-subbituminous coal (0.38%R_or), Hat Creek Formation, Hat Creek Coalfield, British Columbia

f. **funginite** (Fg) from fungal sclerotia; Paleocene lignite (0.36%R_or), Estevan Seam, Ravenscrag Formation, Estevan Coalfield, southeastern Saskatchewan

g. **funginite** (Fg) from fungal spores; Paleocene lignite (0.36%R_or), Estevan Seam, Ravenscrag Formation, Estevan Coalfield, southeastern Saskatchewan

h. **funginoids** (Fg); Paleocene lignite (0.32%R_or), Summit Creek Formation, Brackett Basin, Northwest Territories

i. **funginite** (Fg); Eocene lignite-subbituminous coal (0.38%R_or), Hat Creek Formation, Hat Creek Coalfield, British Columbia

j. **macrinite** (Ma), derived by oxidation of gelinite (levigelinite), has inherited the characteristic shrinkage/desiccation cracks commonly observed in the huminitic precursor; Paleocene lignite (0.32%R_or), Summit Creek Formation, Brackett Basin, Northwest Territories

k. highly reflective, **macrinite** (Ma) in densinite groundmass; Paleocene lignite (0.31%R_or), Hart Seam, Ravenscrag Formation, Willow Bunch Coalfield, south-central Saskatchewan

l. high concentrations of granular **micrinite** (Mi), associated with dark liptinites (var: cutinite, Cu) from Eocene lignite-subbituminous coal (0.38%R_or), Hat Creek, British Columbia

m. **inertodetrinite** (Id) particles less than 5 μm (arrows) and sub-micron sized **micrinite** (Mi), dispersed throughout the densinite groundmass which includes suberinite, cutinite and sporinite; Paleocene lignite (0.32%R_or), Summit Creek Formation, Brackett Basin, Northwest Territories

MINERAL MATTER

n,o. epigenetic **pyrite** (Py) infilling fractures in ulminite; Paleocene lignite (0.36%R_or), Hart Seam, Ravenscrag Formation, Willow Bunch Coalfield, south-central Saskatchewan

p. **pyrite** (Py) framboids in ulminite; lignite (0.32-40%R_or), Paleocene Summit Creek Formation, Brackett Basin, Northwest Territories; (ulminite is underexposed and therefore appears significantly darker than in microscope view)

q. Epigenetic **carbonate minerals** (Ca) embedded in huminite; Paleocene lignite-subbituminous coal (0.38-0.40%R_or), Hat Creek Formation, Hat Creek Coalfield, British Columbia

r. **Carbonate-filled cavities** (Ca) in **fusinite** (F); Eocene lignite-subbituminous coal (0.38-0.40%R_or), Hat Creek Formation, Hat Creek Coalfield, British Columbia

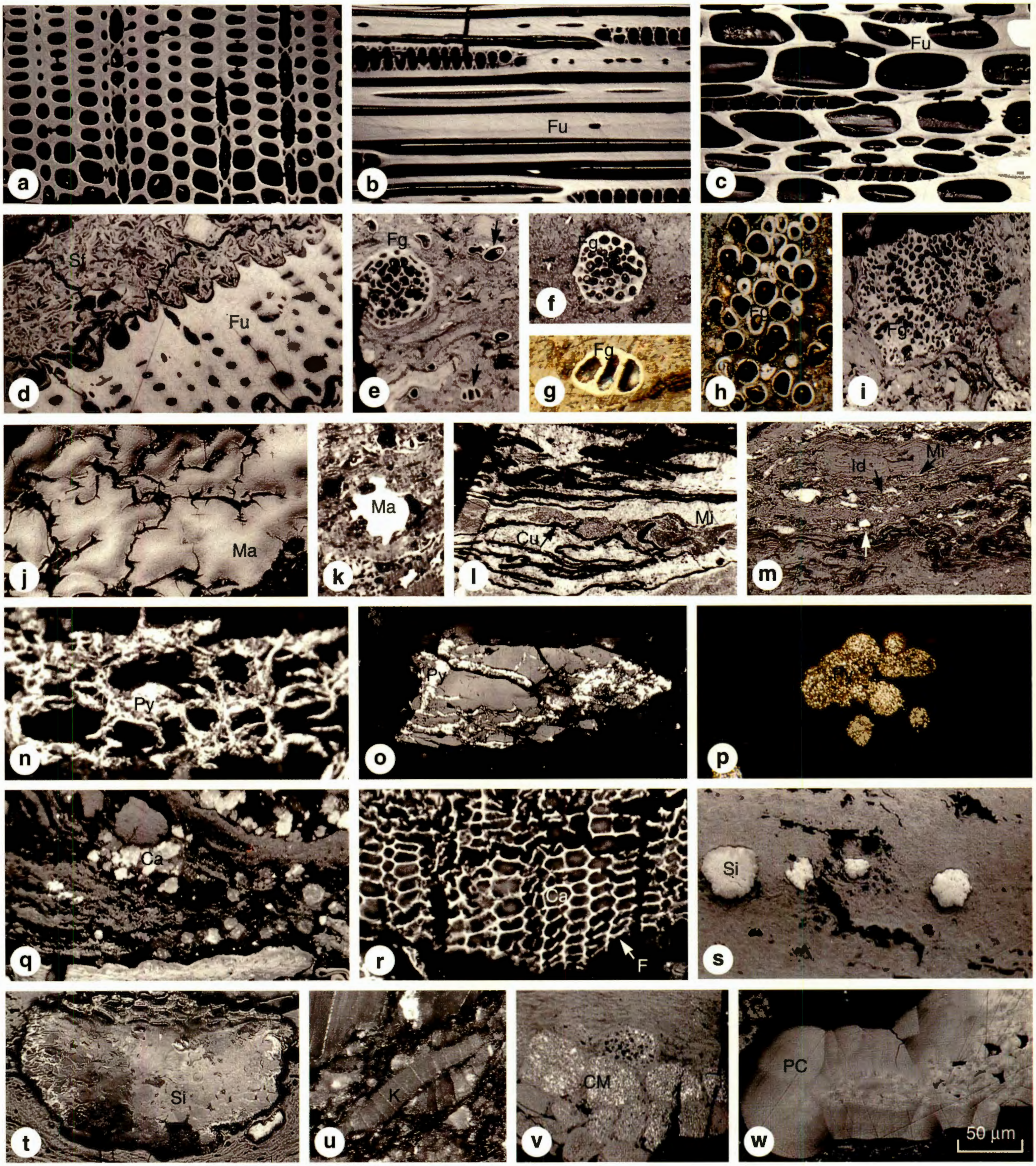
s. **Siderite** (Si) embedded in huminite; Eocene lignite-subbituminous coal (0.38-0.42%R_or), Hat Creek Formation, Hat Creek Coalfield, British Columbia

t. **Siderite** (Si) concretion; Upper Cretaceous subbituminous coal (0.42%R_or), Horseshoe Canyon Formation, Sheerness Coalfield, southeastern Alberta

u. vermicular **kaolinite** (K); Upper Cretaceous subbituminous coal (0.42%R_or), Horseshoe Canyon Formation, Sheerness Coalfield, southeastern Alberta

v. **clay minerals** (CM) associated with phlobaphenite and corpohuminites; Eocene lignite-subbituminous coal (0.38-0.42%R_or) from Hat Creek Formation, Hat Creek Coalfield, British Columbia

w. **pyrolitic carbon** (PC); Paleocene lignite (0.32%R_or), Summit Creek Formation, Brackett Basin, Northwest Territories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REFERENCES: LIGNITES AND SUBBITUMINOUS COALS OF CANADA

Beaton, A.P. (1989). The organic petrology and geochemistry of lignites from the Paleocene Ravenscrag Formation, southern Saskatchewan, Canada. M.Sc. Thesis, University of Regina, Regina, Saskatchewan, 130 p.

Beaton, A.P. and Goodarzi, F. (1990). The geochemistry of lignites from southern Saskatchewan, Canada. Journal of Coal Quality, V. 8: 110-116.

Beaton, A.P. and Goodarzi, F. (1995). Characterization of lignites from southern Saskatchewan, Canada. Geological Survey of Canada, Report 95-3: 255-278.

Beaton, A.P., Potter, J. and Goodarzi, F. (1991). Petrography, mineralogy and geochemistry of Paleocene lignite from southern Saskatchewan. International Journal of Coal Geology, V. 17: 17-48.

Bustin, R.M. (1986). Organic maturity of Late Cretaceous and Tertiary coal measures, Canadian Arctic Archipelago. International Journal of Coal Geology, V. 6: 71-106.

Bustin, R.M. (1991). Organic maturation of the Western Canadian Sedimentary Basin. International Journal of Coal Geology, V. 19: 319-358.

Cameron, A.R. (1978). Petrographic characteristics of lignites from the Estevan Area. In: Coal Resources of Southern Saskatchewan: A Model for Evaluation Methodology, J.A. Irvine, S.H. Whitaker and P.L. Broughton (eds.). Geological Survey of Canada Economic Report 30, Part I, 156 p. (See also Saskatchewan Department of Mineral Resources Report 209; Saskatchewan Research Council Report 20.)

Cameron, A.R. (1991). Regional patterns of reflectance in lignites of the Ravenscrag Formation, Saskatchewan, Canada. Organic Geochemistry, V. 17: 223-242.

Cameron, A.R. (1993). Coal, subchapter 6B. In: Sedimentary Cover of the Craton in Canada, D.F. Stott and J.D. Aitken (eds.). Geological Survey of Canada, Geology of Canada, No. 5: 563-598. (Also Geological Society of America, the Geology of North America, V. D-1.)

Cameron, A.R. and Birmingham, T.F. (1971). Petrographic and chemical properties of a lignite from Estevan, Saskatchewan, Canada. Geological Survey of Canada, Department of Energy, Mines and Resources, Paper 71-8, 20 p.

Cameron, A.R. and Marconi. L. (1979). Reflectance measurements on ulminite from Saskatchewan lignites: Geological Society of America, Abstracts with Programs, V. 11: 397.

Dawson, F.M., Cameron, A.R. and Jerzykiewicz, T. (1982). Distribution and character of coal in the Battle River Coalfield, east-central Alberta. In: Contributions to Canadian Coal Geoscience, Geological Survey of Canada, Paper 89-8: 49-61.

Dawson, F.M. and Kalkreuth, W.D. (1989). Preliminary results of a continuing study of the stratigraphic context, distribution and characteristics of coals in the Upper Cretaceous to Paleocene Wapiti Group, northwestern Alberta. In: Contributions to Canadian Coal Geoscience, Geological Survey of Canada, Paper 89-9: 43-48.

Deck, D.M. (1985). A review and investigation of wood charcoal analysis and the formation of a charcoal reference collection. B.A. Hons. Thesis, Department of Anthropology, University of Regina.

Demchuk, T., Cameron, A.R. and Hills, L.V. (1993). Organic Petrology of an early Paleocene coal zone, Wabamun, Alberta: palynology, petrography and geochemistry. Organic Geochemistry, V. 20: 135-148.

Gentzis, T. and Goodarzi, F. (1990). Petrology, depositional environment and utilization potential of Late Paleocene coals from the Obed-Marsh deposit, west-central Alberta, Canada. International Journal of Coal Geology, V. 16: 287-308.

Gentzis, T., Goodarzi, F. and Lali, K. (1990). Petrographic study of Upper Cretaceous brackish coals from Vesta mine, east-central Alberta. In: Current Research, Part D, Geological Survey of Canada, Paper 90-1D: 187-193.

Gentzis, T., Goodarzi, F. and Gibson, D.W. (1992). A petrographic study of the coal-bearing strata in the Drumheller area, Red Deer River valley, Alberta. In: Current Research, Part B, Geological Survey of Canada, Paper 92-1B: 79-89.

Gentzis, T., and Goodarzi, F. (1994). Suppression of reflectance in Cretaceous coals from Alberta, Canada. In: Vitrinite Reflectance as a Maturity Parameter, P.K. Mukhopadhyay and W.G. Dow (eds.). American Chemical Society Symposium Series, No. 570, Ch. 7: 93-110.

Goodarzi, F. and Gentzis, T. (1987). Depositional setting, determined by organic petrology, of the Middle Eocene Hat Creek No. 2 Coal Deposit, British Columbia, Canada. Bulletin of Canadian Petroleum Geology, V. 35: 197-211.

Goodarzi, F., Gentzis, T., Feinstein, S. and Snowdon, L.R. (1988). Effect of maceral subtypes and mineral matrix on measured reflectance of subbituminous coals and dispersed organic matter. International Journal of Coal Geology, V. 10: 383-398.

Goodarzi, F., Snowdon, L.R., Gentzis, T. and Pearson, D.E. (1994). Petrological and chemical characteristics of liptinite-rich coals from Alberta, Canada. Marine and Petroleum Geology, V. 11, pt. 3: 307-319.

Hagemann, H.W. (1981). Identification of the lithotypes in lignites of southern Saskatchewan, Part I. Geological Survey of Canada, Open File Report, 67 p.

Hawke, M. (1997). Petrography of cold climate peats of Ontario, Canada: modern analogues for Permian Gondwana coals. Unpublished M.Sc. Thesis, University of Guelph, 192 p.

Hughes, J.D. and Long, D.G.F. (1980). Geology and coal resource potential of the Early Tertiary strata along the Tintina Trench, Yukon Territory. Geological Survey of Canada, Paper 79-32, 21 p.

Long, D.G.F. (1978). Lignite deposits in the Bonnet Plume Formation, Yukon Territory. In: Current Research, Part A, Geological Survey of Canada, Paper 78-1A: 399-401.

Marchioni, D.L. (1983). The detection of weathering in coal by petrographic, rheological and chemical methods. International Journal of Coal Geology, V. 2: 231-259.

Marchioni, D.L. (1985). Reflectance studies in brown coals: An example from the Hat Creek deposit of British Columbia, A.T. Cross (ed.). Neuvième Congres International de Stratigraphie et Géologie du Carbonifère Washington-Urbana, May 17-26, 1979, Compte Rendu 4: 590-599.

McDougall, W.J. (1989). Characterization of coals from the Ravenscrag Formation, southern Saskatchewan, Canada. M.Sc. thesis, University of Regina, Regina, Saskatchewan, 116 p.

McDougall, W.J. and Potter, J. (1987). Petrographic characteristics of coals from the Ravenscrag Formation, southern Saskatchewan: Implications for coal utilization. In: Economic Minerals of Saskatchewan, C.F. Gilboy and L.W. Vigrass (eds.). Special Publication No. 8, Saskatchewan Geological Society, Regina, Saskatchewan: 187-196.

McDougall, W.J. and Potter, J. (1987). Characterization of coals from the Ravenscrag Formation, southern Saskatchewan. Canada-Saskatchewan Heavy Oils-Fossil Fuel Research Program, Technical Report No. 3, 114 p.

Nambudiri, E.M.V. (1987). Peat-forming flora in the Ravenscrag Formation, southern Saskatchewan: Energy Research Unit, University of Regina, Contribution No. 175, 28 p.

Parkash, S., du Plessis, M.P., Cameron, A.R. and Kalkreuth, W.D. (1984). Petrography of low rank coals (Alberta) with reference to liquefaction potential. International Journal of Coal Geology, V. 4, 3: 209-234.

Parkash, S. (1985). Petrographic studies of coals from Alberta Plains. Alberta Research Council Information Series, Bulletin 50, 47 p.

Potter. J., Beaton, A.P., McDougall, W.J., Nambudiri, E.M.V. and Vigrass, L.W. (1991). Depositional environments of the Hart Coal Zone (Paleocene), Willow Bunch Coalfield, southern Saskatchewan, Canada, from petrographic, palynological, paleobotanical and trace element studies. International Journal of Coal Geology, V. 19: 253-282.

Styan, W.B. and Bustin, R.M. (1983). Petrography of some Fraser River Delta peat deposits; coal maceral and microlithotype precursors in temperate-climate peats. International Journal of Coal Geology, V. 2: 321-370.

Sweet, A.R. and Cameron, A.R. (1991). Palynofacies, coal petrographic facies and depositional environments: Amphitheatre Formation (Eocene to Oligocene) and Ravenscrag Formation (Maastrichtian to Paleocene), Canada. International Journal of Coal Geology, V. 19: 121-144.

Sykes, R., Fowler, M.G. and Pratt, K.C. (1994). A plant tissue origin for ulminites A and B in Saskatchewan and lignites and implications for Ro. Energy and Fuels, 8: 1402-1416.

HIGH VOLATILE BITUMINOUS COALS

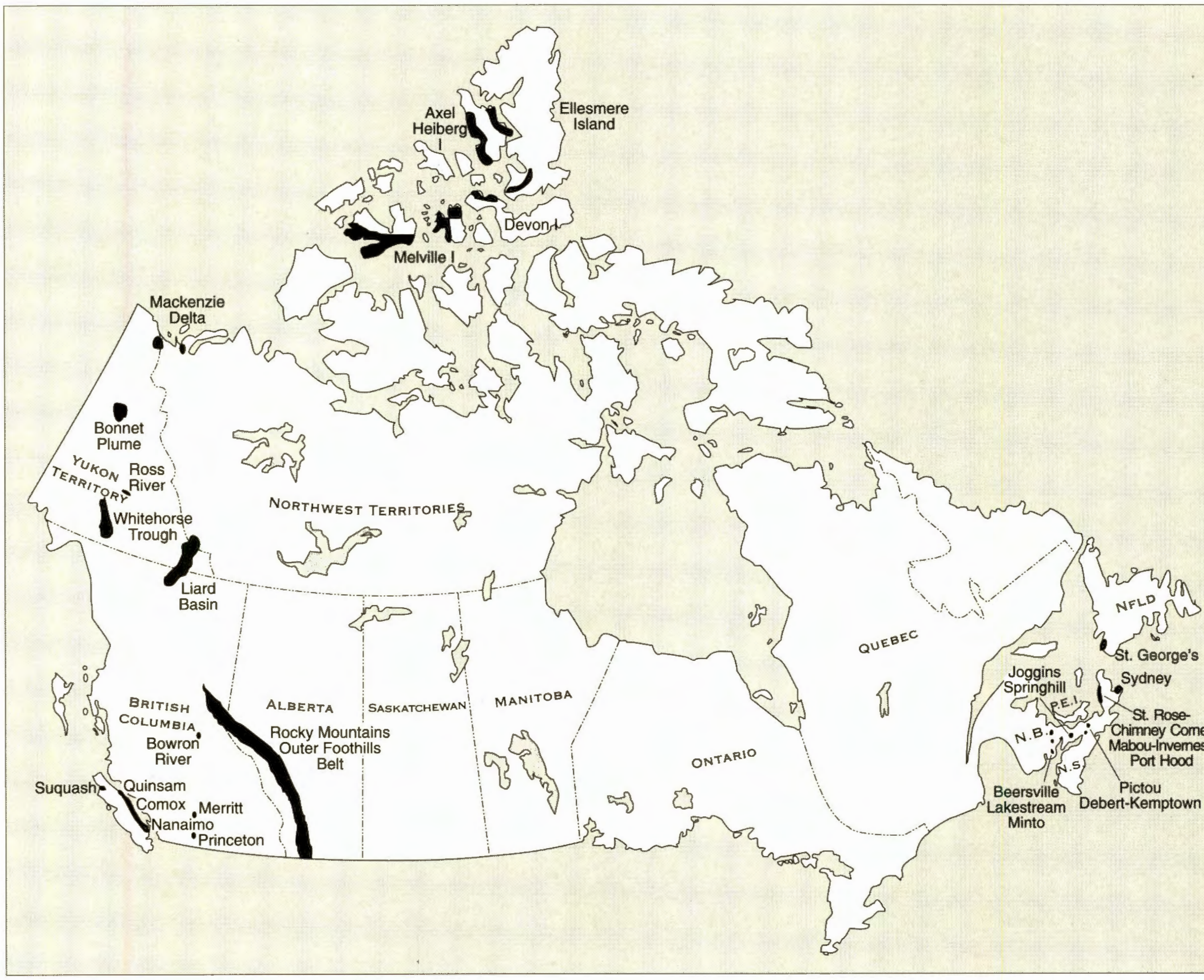


Figure 4a. High volatile bituminous coal deposits

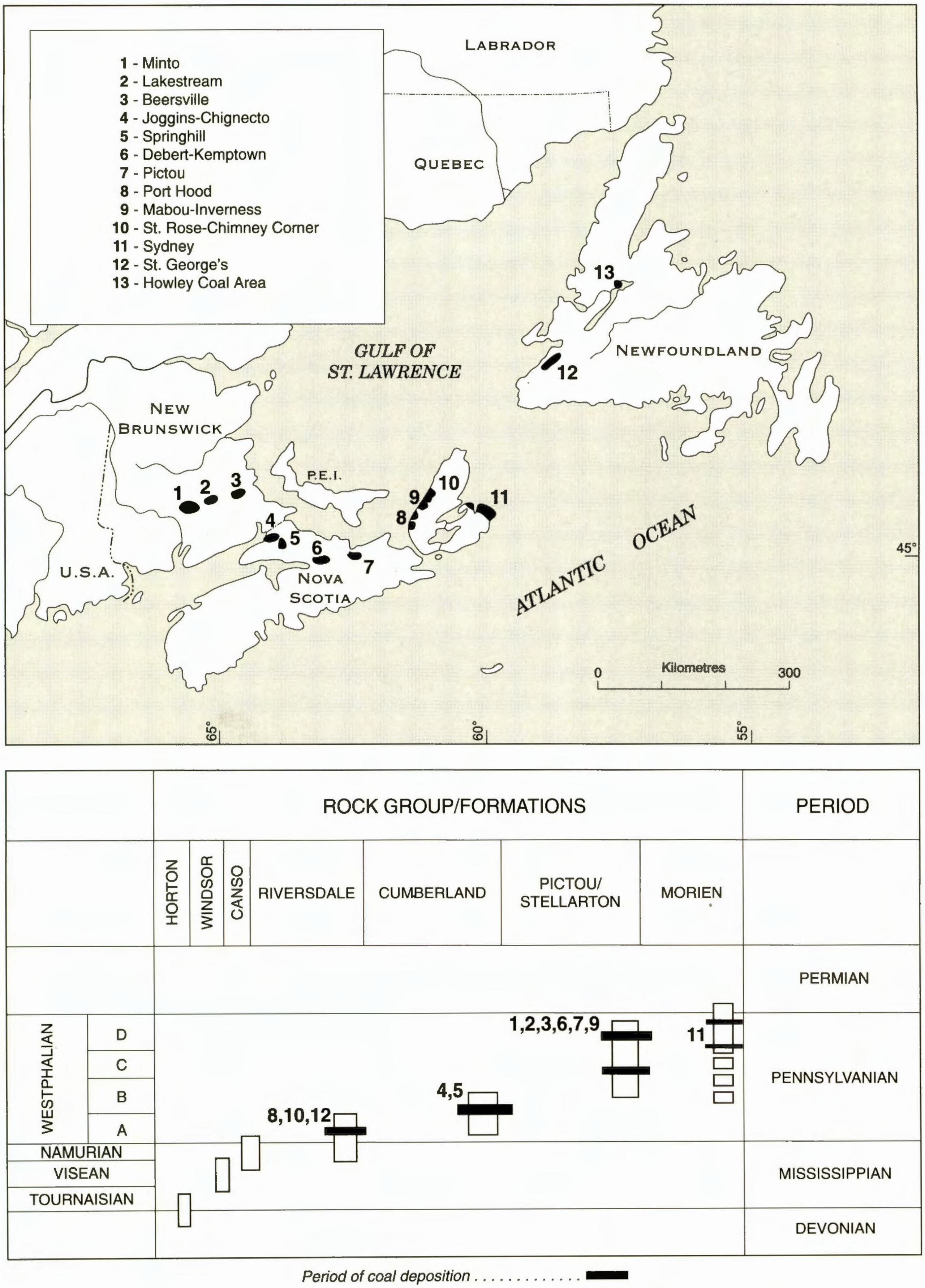


Figure 4b. Coalfields and coal-bearing formations, Atlantic provinces

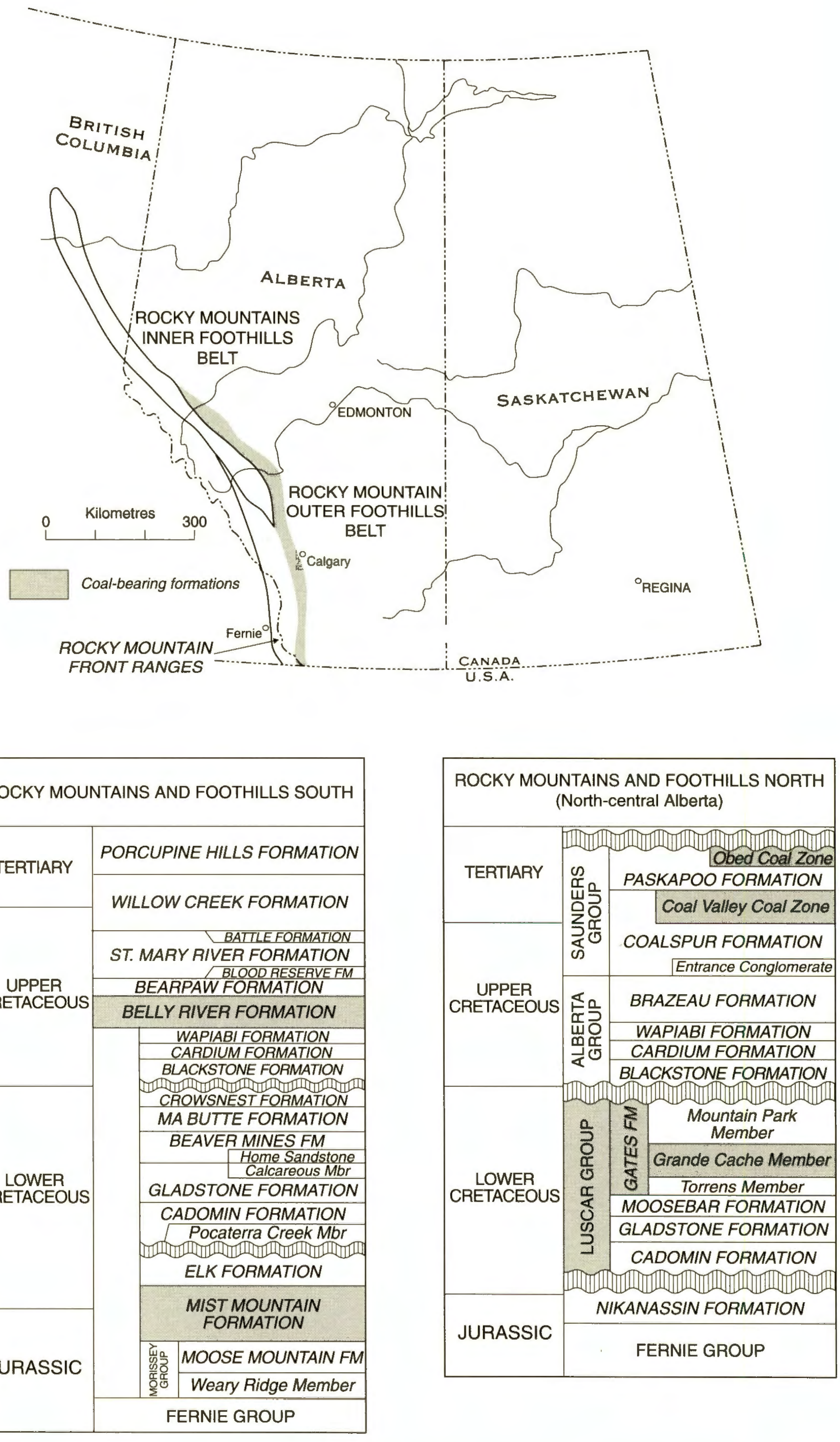


Figure 4c. Coal-bearing formations of the Rocky Mountains and Foothills

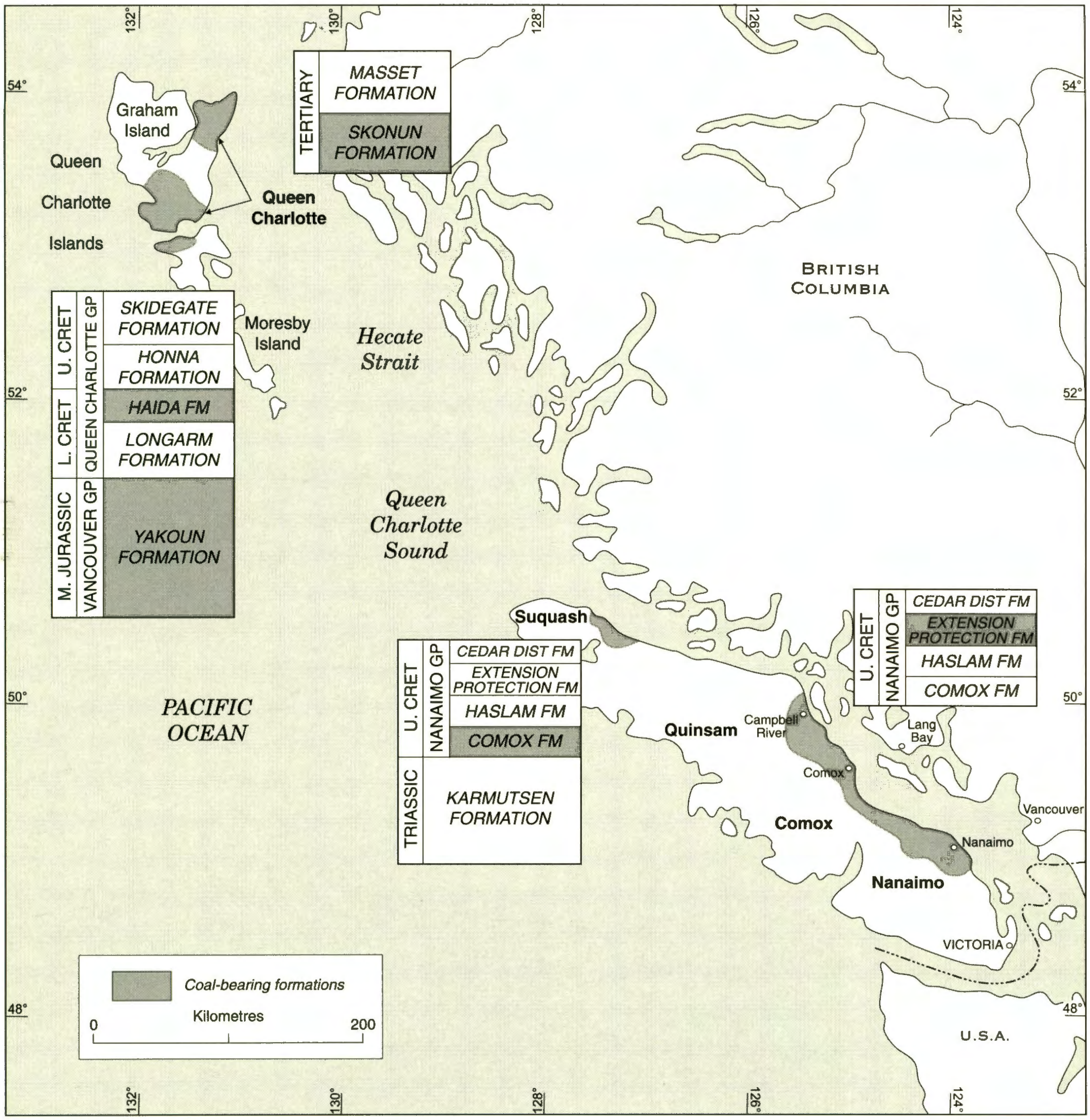
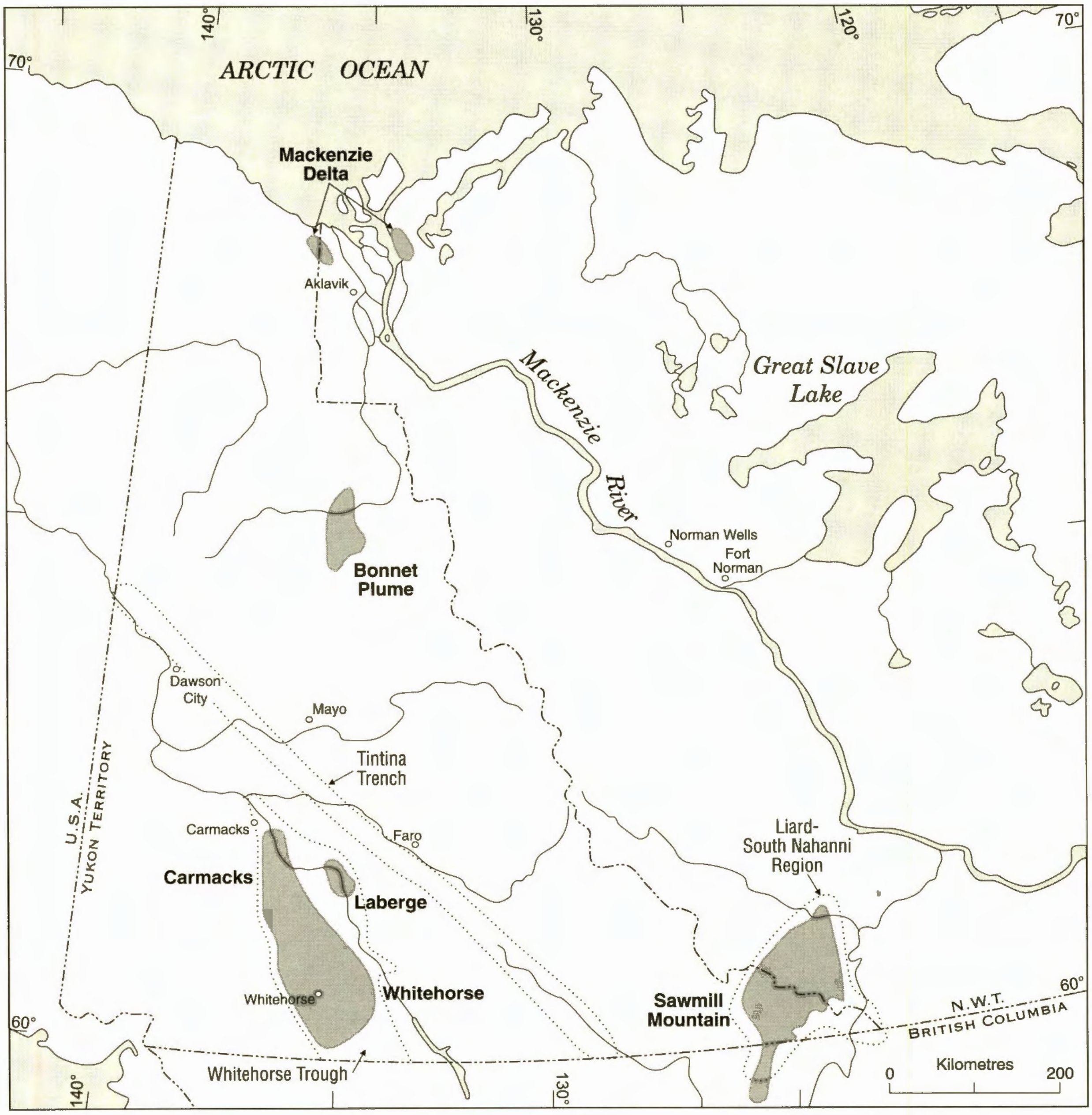


Figure 4d. Coalfields and coal-bearing formations, coastal British Columbia



	Whitehorse Trough	Liard-South Nahanni	Bonnet Plume	Mackenzie Delta
TERTIARY			BONNET PLUME FM	REINDEER FM
CRETACEOUS	TANTALUS FM			
JURASSIC	LABERGE GP			
TRIASSIC				
PERMIAN-PENNSYLVANIAN				
MISSISSIPPIAN		MATTSON FM		

Coal-bearing formations

Figure 4e. Coalfields/basins and coal-bearing formations of the Yukon and Northwest territories

PLATE 5

HIGH VOLATILE BITUMINOUS COALS
VITRINITE MACERALS

All photomicrographs were taken using white incident light and oil immersion objectives
magnification: same for all photos; see scale bar in photo l
coal rank: $\%R_o r$ = mean random reflectance, in oil; $\%R_o m$ = mean maximum reflectance, in oil

a. highly-gelified **collotelinite** (Ct) and **collodetrinite** (Cd) with minor **corpogelinite** (Cg) inclusions, pyrite (Py) and micrinite (Mi); 0.60%$R_o m$; Forty Brine Seam, Westphalian A, Joggins Formation, Cumberland Basin (Joggins coalfield), Nova Scotia

b. **collotelinite** (Ct) with **gelinite**[1] inclusions (G); 0.82%$R_o r$; Foord Seam, Westphalian C, Stellarton Formation (Albion Member), Stellarton Basin (Pictou coalfield), Nova Scotia

c. **collodetrinite** (Cd) and **corpogelinite** (Cg) with pyrite (Py), micrinite (Mi) and liptinite (Lp); 0.60% $R_o m$; Forty Brine Seam, Westphalian A, Joggins Formation, Cumberland Basin (Joggins coalfield), Nova Scotia

d. **vitrodetrinite** (Vd) with clay minerals (Mm), pyrite (Py) and inertodetrinite (Id); 0.86%$R_o r$; McGregor Seam, Westphalian C, Stellarton Formation (Albion Member), Stellarton Basin (Pictou coalfield), Nova Scotia

e. **collodetrinite** (Cd) and **corpogelinite** (Cg) with liptinite (Lp) and inertodetrinite (Id); 0.97%$R_o r$; Acadia Seam, Westphalian B-C, Stellarton Formation (Westville Member), Stellarton Basin (Pictou coalfield), Nova Scotia

f. **corpogelinite** (Cg) and **gelinite**[1] (G); 0.88%$R_o r$; No.7 Seam, Westphalian B, Springhill Mines Formation, Cumberland Basin (Springhill coalfield), Nova Scotia

g. highly gelified **collotelinite** (Ct), **collodetrinite** (Cd) and minor **gelinite** (G), sporinite (Sp); 0.92%$R_o r$; Harbour Seam, Westphalian D, Sydney Mines Formation, Sydney Basin (Sydney coalfield), Nova Scotia

h. highly gelified **collotelinite** (Ct) with minor **gelinite**[1] (G); 0.92%$R_o r$; Harbour Seam, Westphalian D, Sydney Mines Formation, Sydney Basin (Sydney coalfield), Nova Scotia

i. **collotelinite** (Ct) showing alteration to **pseudovitrinite** (Psv); 0.91%$R_o r$; Foord Seam, Westphalian C, Stellarton Formation (Albion Member), Stellarton Basin, Nova Scotia

j. **telinite** (T) with resinite (R) filling cell lumens; 0.70%$R_o m$; Main (Cairnes) Seam, Mid-Late Jurassic, Tanglefoot Formation, Laberge Group, Braeburn coal district, Yukon Territory

k. **collotelinite** (Ct) with some **pseudovitrinite** (Psv) characteristics; 0.70%$R_o m$; Main (Cairnes) Seam, Mid-Late Jurassic, Tanglefoot Formation, Laberge Group, Braeburn coal district, Yukon Territory

l. **collotelinite** (Ct) with possible alteration to **pseudovitrinite** (Psv); 0.70%$R_o m$; Main (Cairnes) Seam, Mid-Late Jurassic, Tanglefoot Formation, Laberge Group, Braeburn coal district, Yukon Territory

m. **collodetrinite** (Cd) with sporinite (Sp) and funginite (Fg) and lenses of **collotelinite** (Ct) with pseudovitrinite characteristics (Psv); 1.03%$R_o m$; Coal zone 2g, Late Jurassic-Early Cretaceous, Tantalus Formation, Carmacks coal district, Yukon Territory

n. **collodetrinite** (Cd) with inertodetrinite (Id), semifusinite (Sf), fusinite (Fu) and sporinite (Sp); 0.76% $R_o m$; Lower Cretaceous Bickford Formation, Peace River Coalfield, inner Foothills Belt, northeastern British Columbia

o. **vitrinite** (V) with suppressed R_o (0.67%), in vitrinertite band including lenses of micrinite (Mi); 0.74%$R_o r$; Lower Carboniferous, Mattson Formation, Clausen Creek (Liard Basin), District of Mackenzie, Northwest Territories

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1 after Mukhopadhyay and Hatcher, 1993

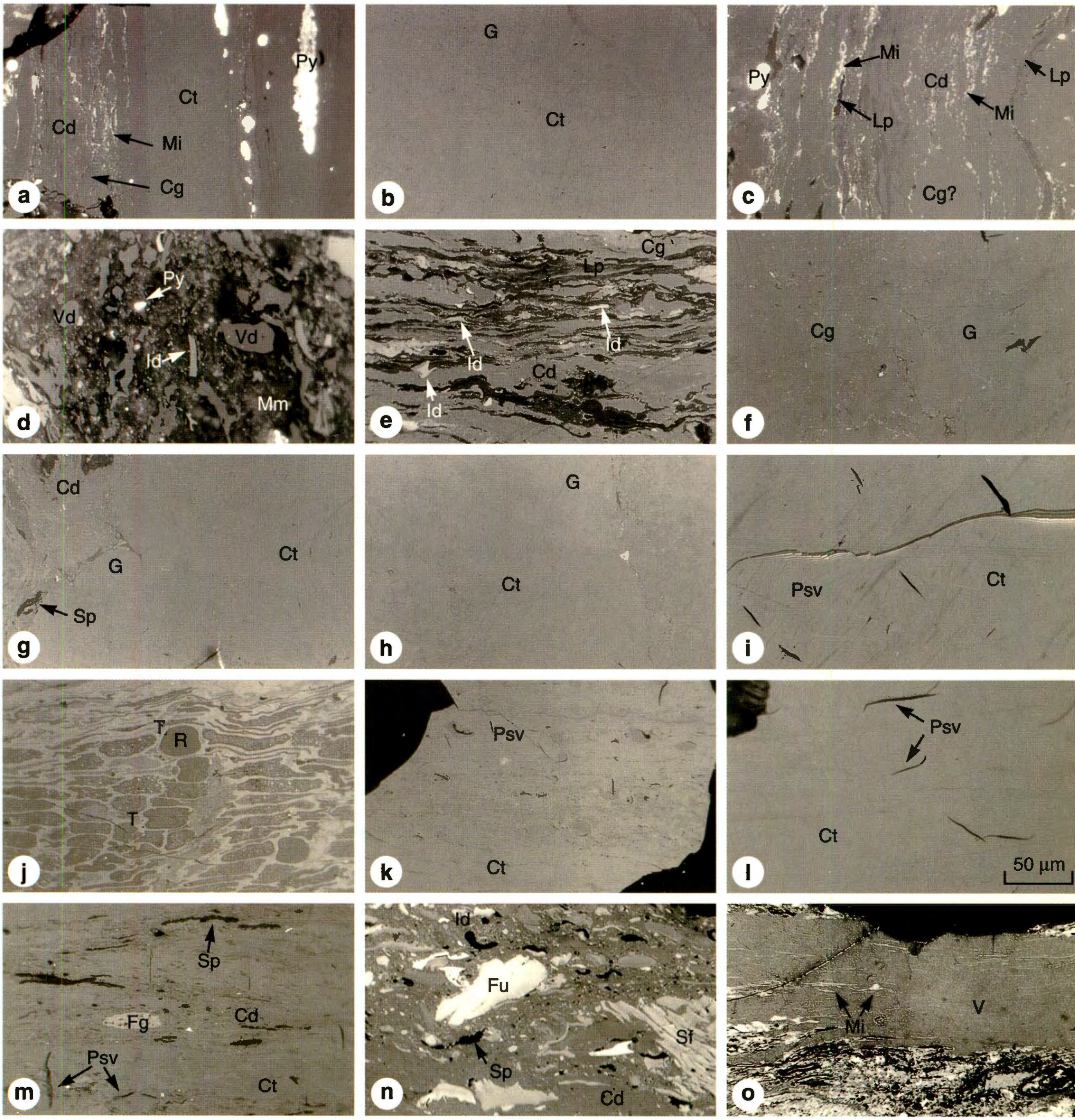
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PLATE 6

HIGH VOLATILE BITUMINOUS COALS VITRINITE AND LIPTINITE MACERALS

All photomicrographs were taken using white incident light under partly crossed polars and oil immersion objectives; **magnification:** same for all photos; see scale bar in photo **p**
coal rank: $\%R_o r$ = mean random reflectance, in oil; $\%R_o m$ = mean maximum reflectance, in oil

Eastern Canada

a. **collotelinite** (Ct) with **cutinite** (Cu) and **corpogelinite** (Cg) enclosing **sporinite** (Sp); 0.60%R_om; Forty Brine Seam, Westphalian A, Joggins Formation, Cumberland Basin (Joggins coalfield), Nova Scotia

b. **collodetrinite** (Cd) and **resinite** (R) (colloresinite?) with **cutinite** (Cu) in upper and mid field; and **sporinite** (Sp) in lower field; 0.92%R_or; Harbour Seam, Westphalian D, Sydney Mines Formation, Sydney Basin, Nova Scotia

c. **collodetrinite** (Cd) and **collotelinite** (Ct) with **suberinite** (Su) and **sporinite** (Sp); 0.82%R_or; Foord Seam, Westphalian C, Stellarton Formation (Albion Member), Stellarton Basin, Nova Scotia

d. **sporinite** (Sp) from megaspores with **vitrodetrinite** (Vd), mineral matter including pyrite (Py) and a band of **collotelinite** (Ct); 0.87%R_or; New Seam, Westphalian C, Stellarton Formation (Albion Member), Stellarton Basin, Nova Scotia

Western Canada

e. **collodetrinite** (Cd) with **cutinite** (Cu); 0.70%R_om; Main (Cairnes) Seam, Mid-Late Jurassic, Tanglefoot Formation, Laberge Group, Braeburn coal district, Yukon

f. **corpogelinite** (Cg) (phlobaphinite cell filling) with **suberinite** (Su); 0.70% R_om; Main (Cairnes) Seam, Mid-Late Jurassic, Tanglefoot Formation, Laberge Group, Braeburn coal district, Yukon Territory

g. thick **cutinite** (Cu); 0.77%R_or; Upper Devonian, Beverley Inlet Formation, western Melville Island, Canadian Arctic

h. as **g**, fluorescent light

i. thick **cutinite** (Cu) associated with **collodetrinite** (Cd) and **liptodetrinite** (Ld); 0.63%R_om; Lower Cretaceous Gorman Creek Formation, Peace River Coalfield, northeastern British Columbia

j. thin **cutinite** (Cu) with characteristic serrated margins associated with **collotelinite** (Ct); 0.71%R_om; Lower Cretaceous Bickford Formation, Peace River Coalfield, northeastern British Columbia

k. **sporinite** (Sp) in **collodetrinite** (Cd) with minor inertodetrinite (Id); needle coal, 0.61%R_om; Lower Cretaceous Bickford Formation, Mount Minnes, northeastern British Columbia

l. high concentrations of **sporinite** (Sp) in **collodetrinite** groundmass; 0.63%R_om; Lower Cretaceous Gorman Creek Formation, Peace River Coalfield, northeastern British Columbia

m. **sporinite** (Sp) in **collodetrinite** (Cd) with inertodetrinite (Id) and semifusinite (Sf); 0.70%R_om; Lower Cretaceous Gething Formation, Peace River Coalfield, northeastern British Columbia

n. **sporinite** (Sp) from megaspore in collodetrinite (Cd) with high concentrations of inertinite (I); 0.68%R_om; Lower Carboniferous Mattson Formation, Jackfish Gap, District of Mackenzie, Northwest Territories

o. **resinite** (R) in **collotelinite** (Ct) matrix; 0.90%R_om; Lower Cretaceous Bickford Formation, Peace River Coalfield, northeastern British Columbia

p. **alginite** (A) with **sporinite** (Sp) and micrinite (Mi); 0.88%R_om; Lower Cretaceous Bickford Formation, Peace River Coalfield, northeastern British Columbia

PLATE 6

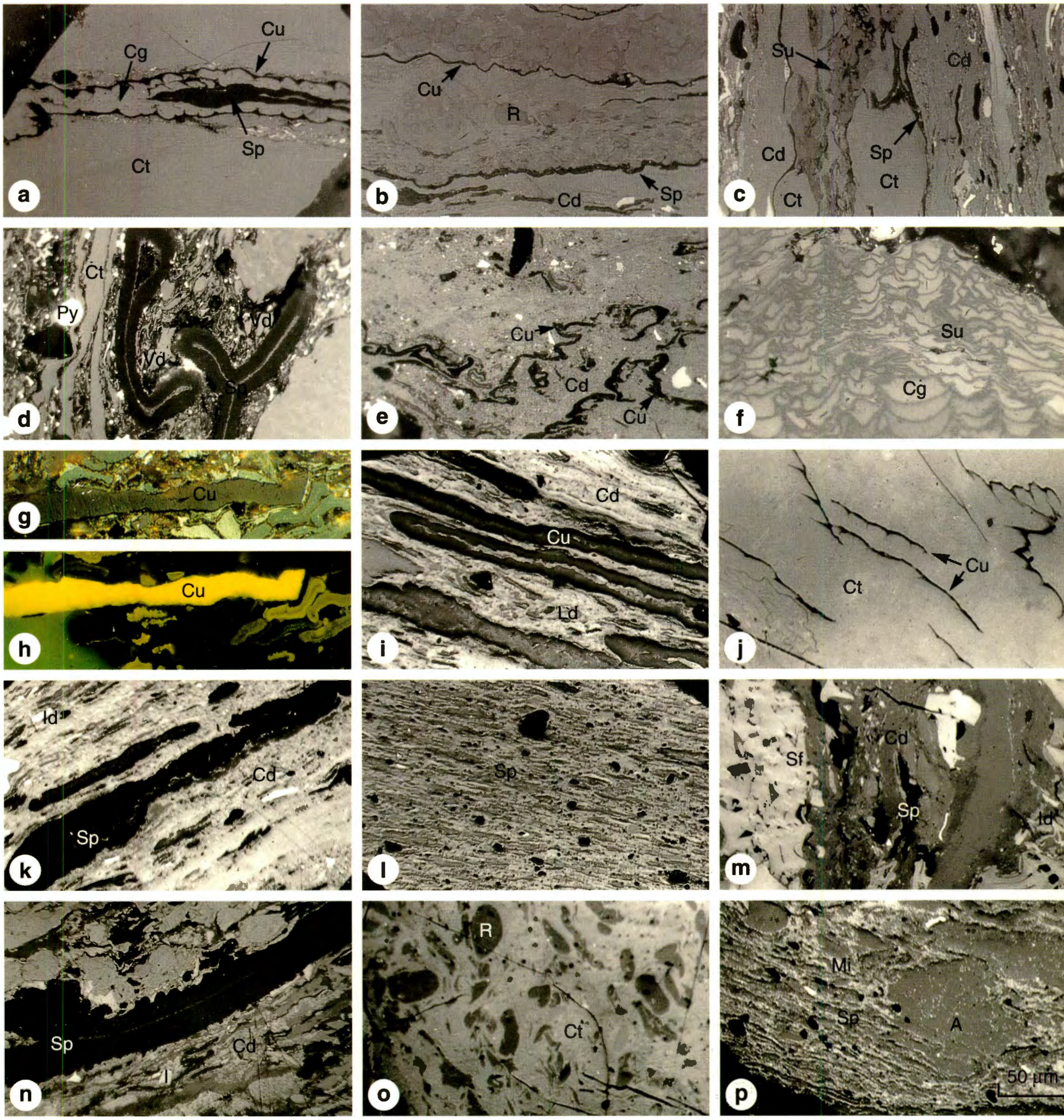
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PLATE 7

HIGH VOLATILE BITUMINOUS COALS
LIPTINITE MACERALS

All photomicrographs were taken using blue incident light and oil immersion objectives
magnification: same for all photos; see scale bar in photo **o**
coal rank: $\%R_{o}r$ = mean random reflectance, in oil; $\%R_{o}m$ = mean maximum reflectance, in oil

Eastern Canada

a. **sporinite** (Sp): sporangium filled with miospores; 0.82$\%R_{o}r$; Foord Seam, Westphalian C, Stellarton Formation (Albion Member), Stellarton Basin, Nova Scotia

b. **sporinite** (Sp), upper field: megaspore; 0.82$\%R_{o}r$; Foord Seam, Westphalian C, Stellarton Formation, Albion Member, Stellarton Basin, Nova Scotia; lower field: miospores; 0.82$\%R_{o}r$; Foord Seam, Westphalian C, Stellarton Formation (Albion Member), Stellarton Basin, Nova Scotia

c. massive **sporinite** (Sp) with alginite (A) inclusion; 0.93$\%R_{o}r$; Harbour Seam (dull band), Westphalian D, Sydney Mines Formation, Sydney Basin, Nova Scotia

d. **fluorinite** (F) with **sporinite** (Sp); 0.71$\%R_{o}r$; Backpit Seam, Westphalian D, Sydney Mines Formation, Sydney Basin, Nova Scotia

e. **cutinite** (Cu) with **resinite** (R), **sporinite** (Sp) and fluorescent vitrinite (fv); 0.82$\%R_{o}r$; Foord Seam, Westphalian C, Stellarton Formation (Albion Member), Stellarton Basin, Nova Scotia

f. **alginite** (A); 0.71$\%R_{o}r$; Bouthillier Seam, Westphalian D, Sydney Mines Formation, Sydney Basin, Nova Scotia

g. fluorescent vitrinite (fv) (vitrinite impregnated with bitumen) with **cutinite** (Cu) and void filled with oil (O); 0.80$\%R_{o}m$; Main Seam, Westphalian A, Port Hood Formation (Colindale Member), Port Hood coalfield, Nova Scotia

h. mineral bituminous groundmass (mbg) (bitumen impregnated mineral matter) with oil droplet (O), **sporinite** (Sp) and **cutinite** (Cu); 0.69$\%R_{o}r$; Bouthillier Seam, Westphalian D, Sydney Mines Formation, Sydney Basin, Nova Scotia

i. **exsudatinite** (Ex) and oil droplets (O); 0.71$\%R_{o}r$; Backpit Seam, Westphalian D, Sydney Mines Formation, Sydney Basin, Nova Scotia

Western Canada

j. **sporinite** (Sp) upper field: megaspore and miospores; Upper Devonian, Beverley Inlet Formation, western Melville Island, Canadian Arctic; 0.77$\%R_{o}r$; lower field: sporangium packed with miospores; Middle Devonian, Hecla Bay Formation, western Melville Island, Canadian Arctic

k. **sporinite** (Sp): megaspore (centre) and miospores (right); 0.76$\%R_{o}r$; Mid-Upper Devonian, Weatherall Formation, Melville Island, Canadian Arctic

l. **resinite** (R), **liptodetrinite** (Ld) and **sporinite** (Sp); 0.79$\%R_{o}r$; Middle Devonian, Hecla Bay Formation, western Melville Island, Canadian Arctic

m. **sporinite** (Sp) derived from thick- and thin-walled miospores with some oil droplets (o); 0.77$\%R_{o}r$; upper Devonian Beverley Inlet Formation, Melville Island, Canadian Arctic

n. **alginite** (A) (*Pila* or *Botryococcus* sp.); 0.77$\%R_{o}r$; Upper Devonian Beverley Inlet Formation, Melville Island, Canadian Arctic

o. **exsudatinite** (Ex) with **liptodetrinite** (Ld) and **sporinite?** (Sp) (transverse section); 0.79$\%R_{o}r$; Middle Devonian, Hecla Bay Formation, western Melville Island, Canadian Arctic

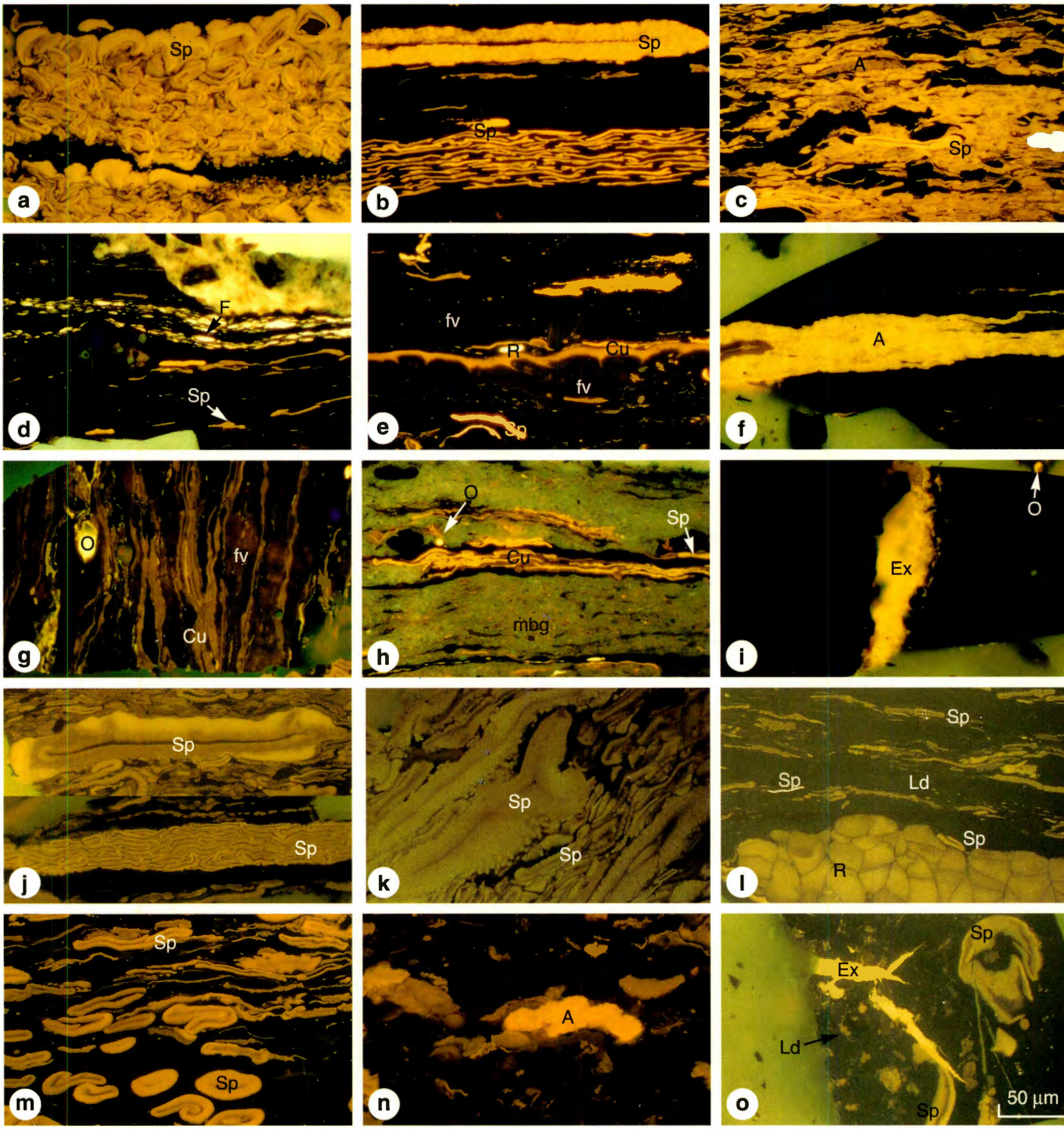
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PLATE 8

HIGH VOLATILE BITUMINOUS COALS
INERTINITE MACERALS

All photomicrographs were taken using white incident light and oil immersion objectives
magnification: same for all photos; see scale bar in photo **o**
coal rank: $\%R_or$ = mean random reflectance, in oil; $\%R_om$ = mean maximum reflectance, in oil

Eastern Canada

a. **fusinite** with well preserved plant cell structure; 0.73$\%R_or$; Backpit Seam, Westphalian D, Sydney Mines Formation, Sydney Basin, Nova Scotia

b. **fusinite** (Fu) and **semifusinite** (Sf) with **inertodetrinite** (Id) with collodetrinite (Cd), quartz (Q) and liptinite (Lp); 0.82$\%R_or$; Foord Seam, Westphalian C, Stellarton Formation (Albion Member), Stellarton Basin (Pictou coalfield), Nova Scotia

c. **semifusinite** (Sf) with collotelinite (Ct) and framboidal pyrite (Py); 0.60$\%R_om$; Forty Brine Seam, Westphalian A, Joggins Formation, Cumberland Basin (Joggins coalfield), Nova Scotia

d. **semifusinite** (Sf) and **inertodetrinite** (Id) with collotelinite (Ct), collodetrinite (Cd) and framboidal pyrite (Py); 0.71$\%R_or$; No. 1 Seam, Westphalian A-B, Springhill Mines, Cumberland Basin (Springhill coalfield), Nova Scotia

e. **fusinite** (Fu), **semifusinite** (Sf), **macrinite** (Ma) and **inertodetrinite** (Id) with collodetrinite (Cd); 0.97$\%R_or$; Acadia Seam, Westphalian B-C, Stellarton Formation (Westville Member), Stellarton Basin (Pictou coalfield), Nova Scotia

f. thick-walled **funginite** (Fg) with **semifusinite** (Sf); 0.60$\%R_om$; Forty Brine Seam, Westphalian A, Joggins Formation, Cumberland Basin (Joggins coalfield), Nova Scotia

g. **inertodetrinite** (Id) and **macrinite** (Ma); 1.06$\%R_or$; Scott Seam, Westphalian B, Stellarton Formation (Westville Member), Stellarton Basin, Nova Scotia

h. **secretinite?** (Se) with **inertodetrinite** (Id), liptinite (Lp) and collodetrinite (Cd); note compression effect around inertinite maceral; 0.60$\%R_or$; St. Rose No. 5 Seam, Westphalian A, Port Hood Formation, St. Rose-Chimney Corner Coalfield, Nova Scotia

i. **micrinite** (Mi) with collodetrinite (Cd), liptinite (Lp) and pyrite (Py); 0.91$\%R_om$; Harbour Seam, Westphalian D, Sydney Mines Formation, Sydney Basin, Nova Scotia

Western Canada

j. **macrinite** (Ma) and **semifusinite** (Sf) with liptinite (Lp) and collodetrinite (Cd); 0.90$\%R_om$; Lower Cretaceous, Bickford Formation, Peace River Coalfield, northeastern British Columbia

k. **fusinite** (Fu) with "bogen" structure; 0.70$\%R_om$; Main (Cairnes) Seam, Mid-Late Jurassic, Tanglefoot Formation, Laberge Group, Braeburn coal district, Yukon Territory

l. **semifusinite** (Sf) with collotelinite (Ct) in centre; 0.70$\%R_om$; Main (Cairnes) Seam, Mid-Late Jurassic, Tanglefoot Formation, Laberge Group, Braeburn coal district, Yukon Territory

m. **semifusinite** (Sf) and **fusinite** (Fu) and **inertodetrinite** (Id); 0.92$\%R_om$; Lower Cretaceous, Gething Formation, Mount Gorman, Peace River Coalfield, northeastern British Columbia

n. **inertodetrinite** (Id) (detrital inertinite with variable reflectance) and vitrodetrinite? (Vd) with collodetrinite (Cd); 0.70$\%R_om$; Main (Cairnes) Seam, Mid-Late Jurassic, Tanglefoot Formation, Laberge Group, Braeburn coal district, Yukon Territory

o. **resino-inertinites** (Ir) or **funginite?** mass with collotelinite (Ct); 1.03$\%R_om$; Coal zone 2g, Late Jurassic-Early Cretaceous, Tantalus Formation, Carmacks coal district, Yukon Territory

PLATE 8

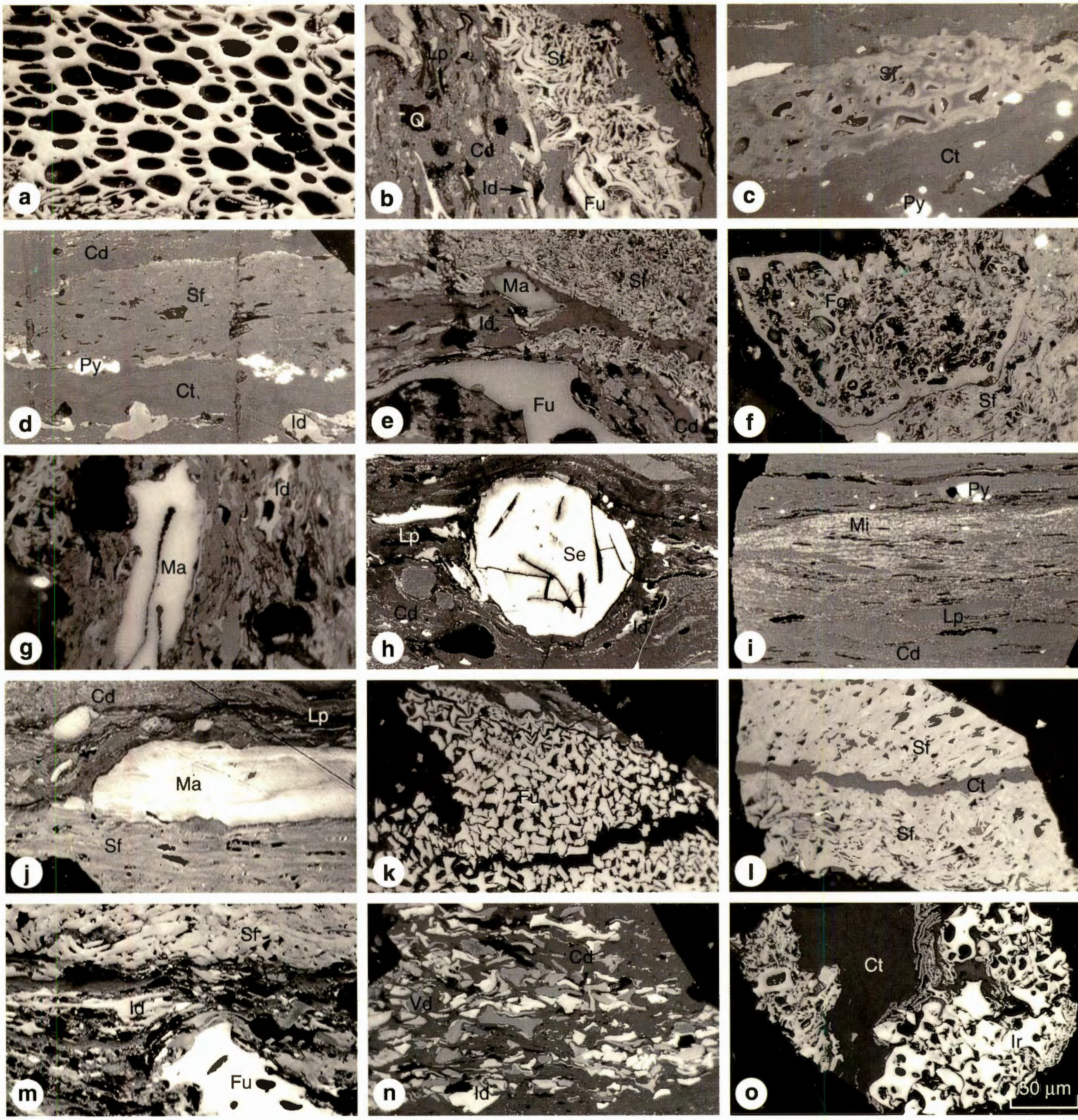
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PLATE 9

HIGH VOLATILE BITUMINOUS COALS
INERTINITES and MINERAL MATTER

All photomicrographs were tken using white incident light and oil immersion objectives
magnification: same for all photos; see scale bar in photo **o**
coal rank: $\%R_o r$ =mean random reflectance, in oil; $\%R_o m$ = mean maximum reflectance, in oil

a. **fusinite** (Fu) showing high relief and "bogen" structure; $0.86\%R_o m$; Lower Cretaceous Bickford Formation, Peace River Coalfield, northeastern British Columbia

b. **fusinite** (Fu) and **semifusinite** (Sf) bands; Pictou Group coal; Pictou Coalfield, Nova Scotia

c. **micrinite** (Mi) grains in high concentrations in sapropelic coal; $0.68\%R_o m$; Lower Carboniferous Mattson Formation, Jackfish Gap, District of Mackenzie, Northwest Territories

d. **resino-inertinites** (Ir); $0.74\%R_o m$; Lower Carboniferous Mattson Formation, Jackfish Gap, District of Mackenzie, Northwest Territories

e. cluster of **resino-inertinites?** (Ir) with collotelinite (Ct); $1.03\%R_o m$; Coal zone 2g, Late Jurassic-Early Cretaceous, Tantalus Formation, Carmacks coal district, Yukon Territory

f. **micrinite** (Mi) interspersed with vitrinite (V) exhibiting suppressed R_o; $0.58\%R_o m$; Lower Carboniferous Mattson Formation, Jackfish Gap, District of Mackenzie, Northwest Territories

g. highly reflective, fine-grained **pyrite** (Py) and **clay minerals** (Cm) with gelinite (G)*; $1.00\%R_o r$; Phalen Seam, Westphalian D Sydney Mines Formation, Sydney Basin, Nova Scotia

h. large **pyrite** framboids (Py); $0.76\%R_o m$; Hub Seam, Westphalian D, Sydney Mines Formation, Sydney Basin, Nova Scotia

i. fine grained, framboidal **pyrite** (Py) with collotelinite (Ct)* and collodetrinite (Cd)*; $0.76\%R_o m$; Minto-Chipman Seam, Westphalian B-C, Minto Formation, Marysville Basin, New Brunswick

j. **calcite** (Ca); $0.76\%R_o r$; Hub Seam, Westphalian D, Sydney Mines Formation, Sydney Basin, Nova Scotia

k. **carbonate** (Ca); $0.87\%R_o r$; New Seam, Westphalian C, Stellarton Formation (Albion Member), Stellarton Basin, Nova Scotia

l. **quartz** (Q) with vitrodetrinite (Vd) and inertodetrinite (Id); $0.76\%R_o m$; Minto-Chipman Seam, Westphalian B-C, Minto Formation, Marysville Basin, New Brunswick

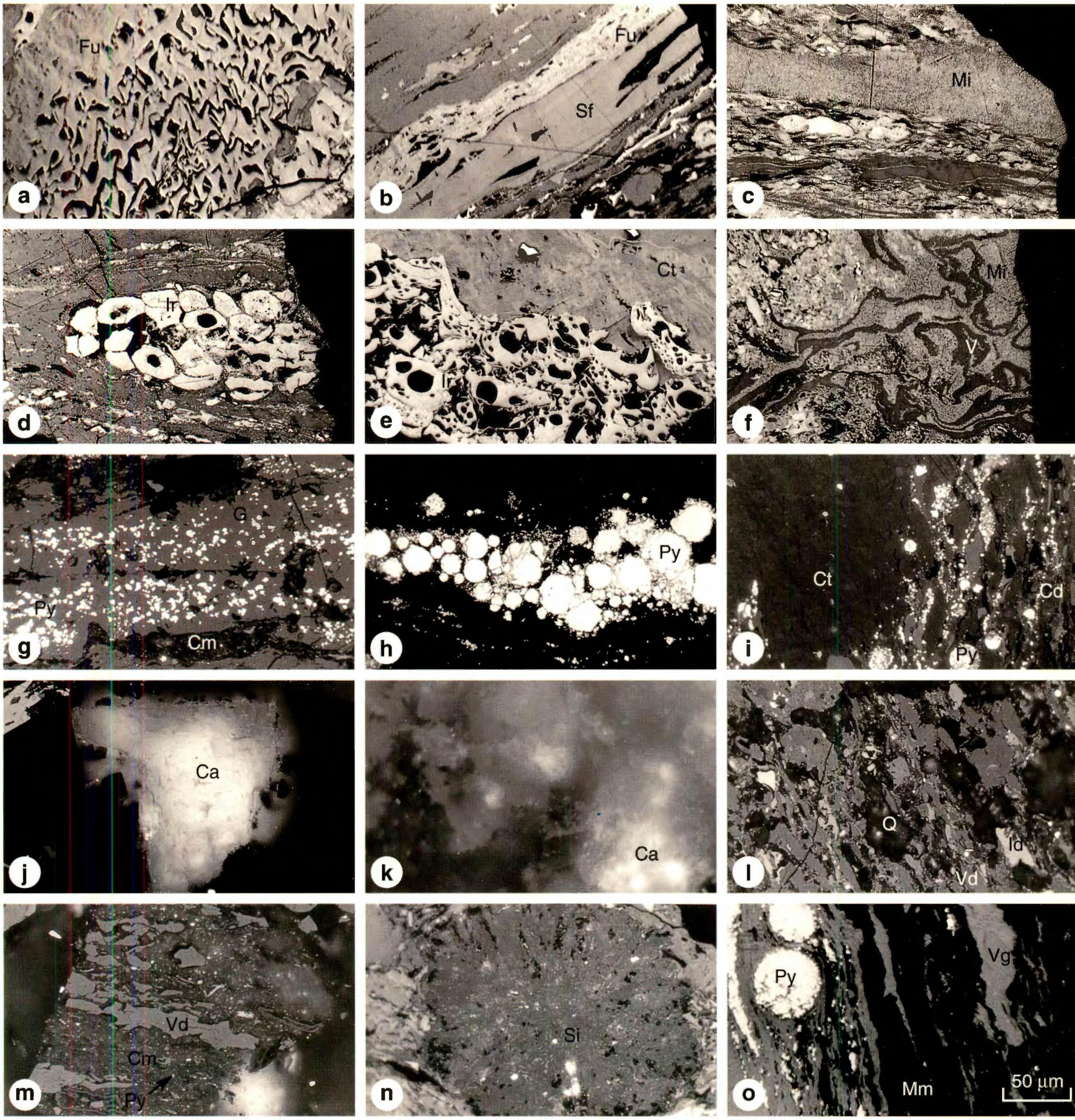
m. **clay minerals** (Cm) and fine grained **pyrite** (Py) with vitrodetrinite (Vd); $0.77\%R_o m$; Debert No. 1 Seam, Westphalian C, Delany Formation, Debert-Kemptown coalfield, Nova Scotia

n. **siderite** (Si); $0.70\%R_o m$; Main (Cairnes) Seam, Mid-Late Jurassic, Tanglefoot Formation, Laberge Group, Braeburn coal district, Yukon Territory

o. **pyrite** (Py) and gelovitrinite (Vg) in shale matrix ?(Mm); $0.80\%R_o m$; BH 81-16, 23.84 m, Lower Cretaceous, Bickford Formation, Peace River coalfield, Rocky Creek area, British Columbia

*The reflectance of the vitrinites in these photos is deliberately suppressed in order to show the pyrite more distinctly; the dark colour of the vitrinite therefore does not reflect the % reflectance expected.

PLATE 9



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Vd
m
Vd
Cm
Py
n
Si
o
Py
Vg
Mm
50 µm

REFERENCES: HIGH VOLATILE BITUMINOUS COALS OF CANADA

Allan, J. and Gehring, K.D. (1989). Evaluation of the petrographic controls on coal quality and thermal reactivity. Alberta Research Council Information Series, Bulletin 103: 133-150.

Beaton, A.P. (in prep). Petrology, geochemistry and geology of coal from the Laberge Group and Tantalus Formation, Whitehorse Trough, Southern Yukon, Canada. Ph.D Thesis, University of Western Ontario, London, Ontario, Canada.

Bustin, R.M. (1982). The effects of shearing on the quality of some coals in the southeastern Canadian Cordillera. Canadian Institute of Mining and Metallurgy, Bulletin, V. 75: 76-83.

Bustin, R.M. and England, J.D. (1989). Timing of Organic Maturation (coalification) relative to thrust faulting in the southeastern Canadian Cordillera. International Journal of Coal Geology, V. 13: 327-339.

Calder, J.H. (1993). Evolution of a groundwater-influenced peat-forming ecosystem in a piedmont setting: the No. 3 seam, Springhill coalfield, Cumberland Basin, Nova Scotia. Geological Society of America, Special Paper 286: 153-180.

Calder, J.H., Gibling, M.R. and Mukhopadhyay, P.K. (1991). Peat formation in a Westphalian B peidmont setting, Cumberland Basin, Nova Scotia: Implications for the maceral-based interpretation of rheotropic and raised paleomires. Bulletin of the Geological Society France, V. 162, 2: 283-298.

Cameron, A.R. (1971). Some petrological aspects of the Harbour coal seam, Sydney Coalfield, Nova Scotia. Geological Survey of Canada, Bulletin 175, 74 p.

Cameron, A.R. (1972). Petrography of Kootenay coals in the upper Elk Valley and Crowsnest areas; Research Council of Alberta Information Series, Bulletin 60: 31-45.

Cameron, A.R. (1984). Comparison of reflectance data for various macerals from coals of the Kootenay Group, southeastern British Columbia. In: Symposium on the Geology of the Rocky Mountain Coal; North Dakota Geological Society Proceedings 1984; Publication 84-1: 61-75.

Cameron, A.R. (1989). Relationship of petrographic and chemical parameters for Western Canadian Coals. Alberta Research Council Information Series, Bulletin 103: 225-232.

Cameron, A.R. (1993). Coal, subchapter 6B. In: Sedimentary Cover of the Craton in Canada, D.F. Stott and J.D. Aitken (eds.). Geological Survey of Canada, Geology of Canada, No. 5: 563-598. (Also Geological Society of America, the Geology of North America, V. D-1.)

Cameron, A.R. and Kalkreuth, W.D. (1982). Petrological characteristics of Jurassic-Cretaceous coals in the Foothills and Rocky Mountains of Western Canada. Proc. 5th Symposium on the Geology of Rocky Mountain Coal; Utah Geological and Mineralogical Survey, Bulletin 118: 163-167.

Fowler, M.G., Goodarzi, F., Gentzis, T. and Brooks, P.W. (1991). Hydrocarbon generating potential of Middle and Upper Devonian coals from Melville Island, Arctic Canada, Organic Geochemistry, V. 17, 6: 681-694.

Gentzis, T. and Goodarzi, F. (1991). Petrology and depositional environment and utilization potential of Devonian cannel coals from Melville Island, Canadian Arctic Islands. Bulletin of the Geological Society of France, V. 162, 2: 239-253.

Gentzis, T., and Goodarzi, F. (1994). Suppression of reflectance in Cretaceous coals from Alberta, Canada. In: Vitrinite Reflectance as a Maturity Parameter, P.K. Mukhopadhyay and W.G. Dow (eds.). American Chemical Society Symposium Series No. 570, Chapter 7, p. 93-110.

Goodarzi, F. and Goodbody, Q. (1990). Nature and depositional environment of Devonian coals from western Melville Island, Arctic Canada. International Journal of Coal Geology, V. 14: 175-196.

Goodarzi, F., Gentzis, T., Snowdon, L.R., Bustin, R.M., Feinstein, S. and Labonté, M. (1993). Effect of mineral matrix and seam thickness on reflectance of vitrinite in high to low-volatile bituminous coals: an enigma. Marine and Petroleum Geology. V. 10: 162-171.

Goodarzi, F., Gentzis, T. and Harrison, J.C. (1994). Petrology and depositional environment of Upper Devonian coals from eastern Melville Island, Arctic Canada, Geological Survey of Canada, Bulletin 450, R.L. Christie and N.J. McMillan (eds.), p. 203-213.

Grieve, D.A. (1993). Geology and rank distribution of the Elk Valley Coalfield, southeastern British Columbia (82G/15, 82J/2, 6,7,10). British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Survey Branch, Bulletin 82, 188 p.

Hacquebard, P.A. (1951). The correlation by petrographic analyses of No. 5 Seam in St. Rose and Chimney Corner Coalfields, Inverness County, Cape Breton Island, Nova Scotia. Geological Survey of Canada, Bulletin 19, 33 p.

Hacquebard, P.A. (1952). Opaque matter in coal. Economic Geology, V. 47: 494-516.

Hacquebard, P.A. (1952). A petrographic evaluation of the Tracey Seam, Sydney Coalfield, Nova Scotia. In: Proc. 2nd Conference on origin and constitution of coal, Crystal Cliffs, Nova Scotia: 293-318.

Hacquebard, P.A. (1972). The Carboniferous of eastern Canada. Compte Rendu, Septième Congrès Internationale de Stratigraphie et de Géologie du Carbonifère, Krefeld, 1971: 68-89.

Hacquebard, P.A. (1979). A geological appraisal of the coals of Nova Scotia. Canadian Mining and Metallurgical Bulletin, February: 76-87.

Hacquebard, P.A. (1986). The Gulf of St. Lawrence Coal Basin; the largest coalfield of eastern Canada. Canadian Mining and Metallurgical Bulletin, V. 80, 906: 67-78.

Hacquebard, P.A. (1977). Rank of coal as an index of organic metamorphism for oil and gas in Alberta; Chapter 3. In: The Origin and Migration of Petroleum in the Western Canada Sedimentary Basin, Alberta, G. Deroo, T.G. Powell, B. Tissot and R.G. McCrossan (eds.). Geological Survey of Canada, Bulletin 262: 11-22.

Hacquebard, P.A. and Birmingham. T. (1973). Petrography of the Val D'Or and Mynheer seams, Coalspur coal area, Alberta. Geological Survey of Canada, Technical Report No. 83-F/2-1, 21 p.

Hacquebard, P.A. and Cameron, A.R. (1989). Distribution and coalification patterns in Canadian bituminous coals and anthracites. International Journal of Coal Geology, V. 13: 207-260.

Hacquebard, P.A. and Donaldson, J.R. (1969). Carboniferous coal deposition associated with floodplain and limnic environments in Nova Scotia. In: Environments of Coal Deposition, Dapples, E.C. and Hopkins, M.E. (eds.), Geological Society America, Special Paper 114: 143-191.

Hacquebard, P.A. and Donaldson, J.R. (1970). Coal metamorphism and hydrocarbon potential in the Upper Paleozoic of the Atlantic Provinces, Canada. Canadian Journal of Earth Sciences, V. 7: 1139-1163.

Hower, J.C. and Calder, J.H. (1997). Maceral and microlithotype analysis of the Hardgrove Grindability of lithotypes from the Phalen coal bed, Cape Breton, Nova Scotia. Minerals and Metallurgical Processing, V. 14: 49-54.

Kalkreuth, W.D. (1982). Rank and petrographic composition of selected Jurassic–Lower Cretaceous coals from British Columbia, Canada. Canadian Society Petroleum Geologists, Bulletin V. 30: 112-131.

Kalkreuth, W.D. and McMechan, M.E. (1984). Regional patterns of thermal maturation as determined from coal rank studies, Rocky Mountain Foothills and Front Ranges north of Grande Cache, Alberta – implications for petroleum exploration. Bulletin of Canadian Petroleum Geology V. 32: 249-271.

Kalkreuth, W.D. and Leckie, D.E. (1989). Sedimentological and petrological characteristics of Canadian Strandplain coals: a model for coal accumulation from the North American Western Interior Seaway. International Journal of Coal Geology, V. 12: 381-324.

Kalkreuth, W.D., Langenberg, W. and McMechan, M. (1989). Regional coalification patterns of Lower Cretaceous coal-bearing strata, Rocky Mountain Foothills and Foreland, Canada – Implications for future exploration. International Journal of Coal Geology, V. 13: 261-302.

Kalkreuth, W.D., Marchioni, D.L., Calder, J.H., Lamberson, M.N., Naylor, R.D. and Paul, J. (1991). The relationship between coal petrography and depositional environments from selected coal basins in Canada. International Journal of Coal Geology, V. 19: 21-76.

Marchioni, D.L. (1983). The detection of weathering in coal by petrographic, rheological and chemical methods. International Journal of Coal Geology, V. 2: 231-259.

Marchioni, D.L., Kalkreuth, W.D., Utting, J. and Fowler, M. (1994). Petrographic, palynological and geochemical analyses of the Hub and Harbour seams, Sydney Coalfield, Nova Scotia, Canada – implications for facies development. Palaeogeography, Palaeoclimatology, Palaeoecology, V. 106: 241-270.

Mukhopadhyay, P.K., MacDonald, D.J., Calder, J.H., Hughes, J.D. and Hatcher, P.G. (1997). Relationship between methane generation/adsorption potential, micropore system, and permeability with composition and maturation – examples from Carboniferous coals of Nova Scotia, Eastern Canada. Proc. International Coalbed Methane Symposium, Tuscaloosa, Alabama, Paper 9733: 183-193.

Mukhopadhyay, P.K., Lajeunesse, G. and Crandlemire, A.L. (1996). Mineralogical speciation of elements in feed coal and their combustion residues from an eastern Canadian coalfield and power plant. International Journal of Coal Geology Special Volume 32, P. Lyons et al. (eds.). Elsevier Publications, Amsterdam, p. 270-310.

Mukhopadhyay, P.K., MacDonald, D.J. and Calder, J.H. (1995). Evaluation of coalbed methane potential of the Stellarton Basin, Nova Scotia, Canada, based on geological, physical, and geochemical properties. Proceedings International Gas Conference (INTERGAS '95), Tuscaloosa, Alabama, Paper 9505, p. 311-320.

Mukhopadhyay, P.K, Calder, J.H. and Hatcher, P.G. (1993). Geological and physiochemical constraints on methane and C6+ hydrocarbon generating capabilities and quality of Carboniferous coals, Cumberland Basin, Nova Scotia, Canada. Proc. 10th Annual International Pittsburgh Coal Conference, p.1074-1079.

Mukhopadhyay, P.K. and Hatcher, P.G. (1993). The composition of coal. In: Hydrocarbons from Coal. B.E. Law and D.D. Rice (eds.). AAPG Studies in Geology Series No. 38: p. 79-118, American Association Petroleum Geologists Press, Tulsa.

Mukhopadhyay, P.K., Hatcher, P.G. and Calder, J.H. (1991). Hydrocarbon generation from deltaic and intermontaine fluviodeltaic coal and coaly shale from the Tertiary of Texas and Carboniferous of Nova Scotia. In: Coal and Terrestrial Organic Matter as a Source Rock for Petroleum, Mukhopadhyay, P.K. et al. (eds.). Organic Geochemistry, V. 17, 6: 765-784, Pergamon Press, Oxford.

Pearson. D.E. (1980). The quality of Western Canadian coking coal. Canadian Institute of Mining and Metallurgy, Bulletin, V. 73: 1-15.

Pearson, D.E. and Grieve, D.A. (1985). Rank distribution and coalification pattern, Crowsnest coalfield, British Columbia, Canada. Proc. 9th International Congress of Carboniferous Stratigraphy and Geology, Washington-Urbana, Illinois, May 1979, Compte Rendu, V. 4: 600-608.

Pearson, D.E and Pearson, J.S. (1983). The reactivity of inertinites in coking coals from British Columbia (abstract). Canadian Institute of Mining and Metallurgy, Bulletin, V. 76: 52.

Pilgrim, J.C. (1983). The mode and occurrence of pyrite in the Sydney Coalfield, Cape Breton, Nova Scotia. Unpublished B.Sc. (Hons.) Thesis, Acadia University, Nova Scotia, 68 p.

Potter, J., Richards, B.C. and Cameron, A.R. (1993). The petrology and origin of coals from the Lower Carboniferous Mattson Formation, southwestern District of Mackenzie, Canada. International Journal of Coal Geology, V. 24: 113-140.

MEDIUM VOLATILE BITUMINOUS COALS

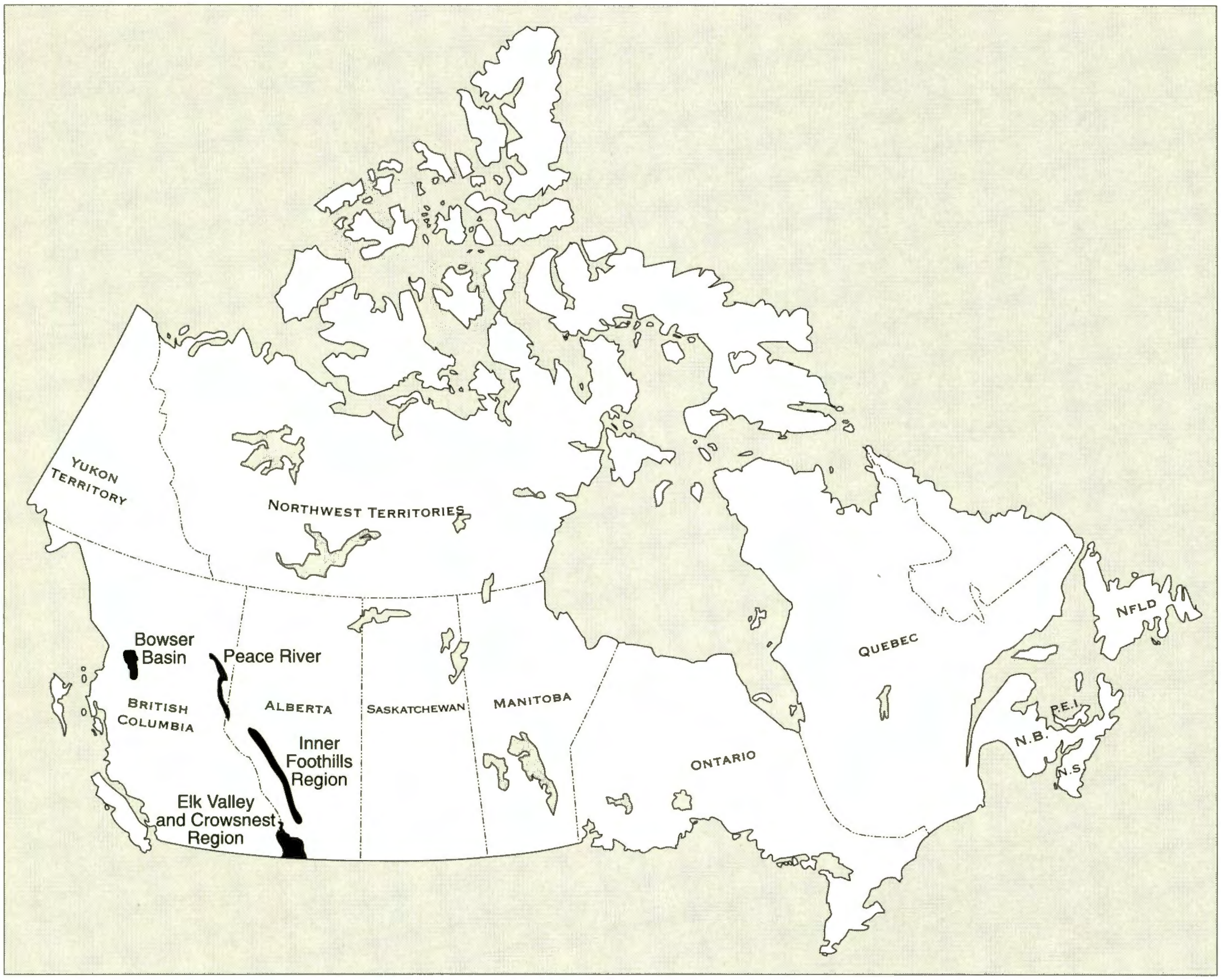

Figure 5a. Medium volatile bituminous coal deposits

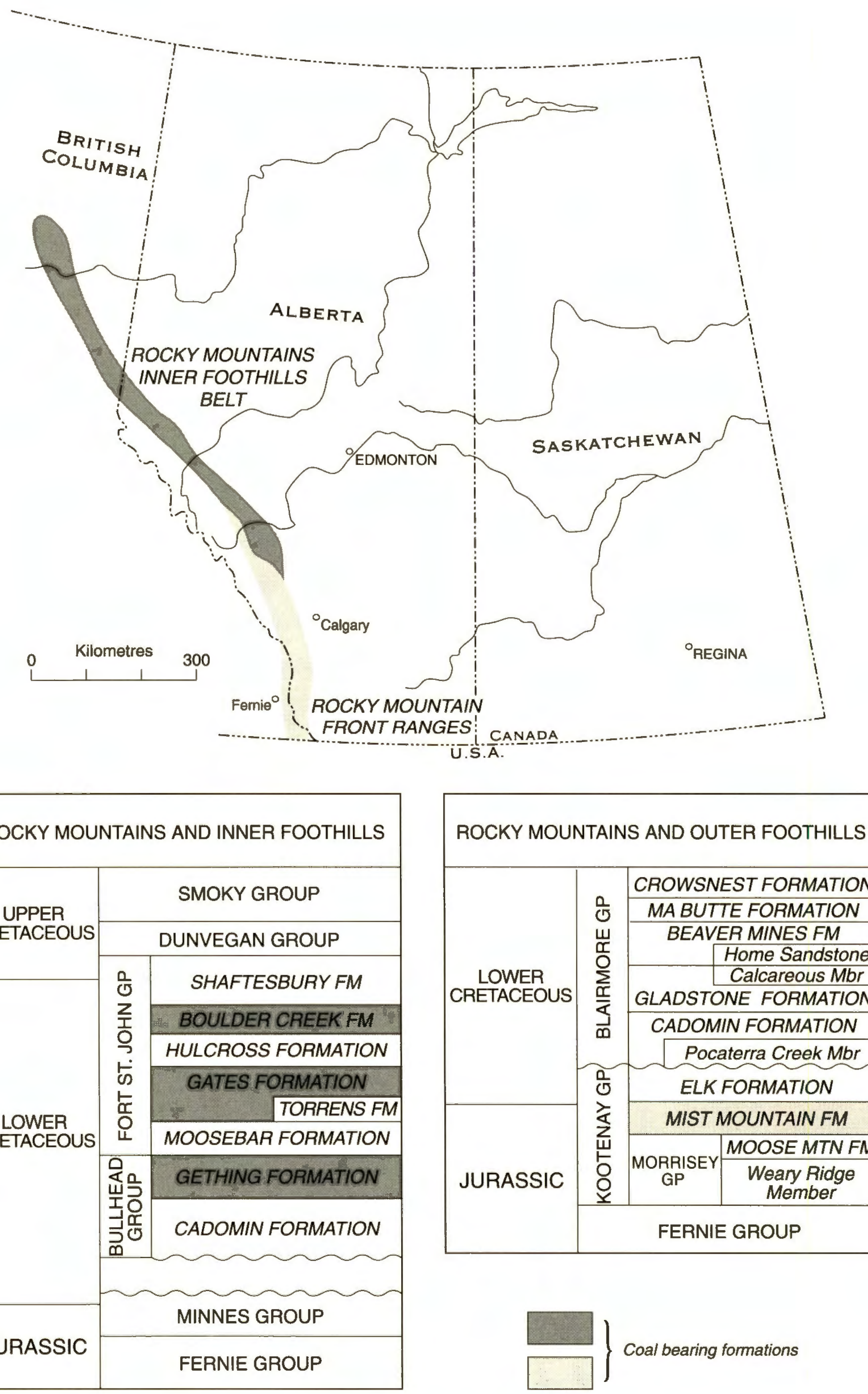

Figure 5b. Coalfields and coal-bearing formations of the Rocky Mountains and Foothills

PLATE 10

MEDIUM VOLATILE BITUMINOUS COALS
VITRINITE MACERALS

All photomicrographs were taken using white incident light and oil immersion objectives
magnification: same for all photos; see scale bar in photo l
coal rank: %R_om = mean maximum reflectance, in oil

a. **collotelinite** (Ct) with well-preserved cell structure and resinite (R) inclusions; 1.16%R_om; Lower Cretaceous Gates Formation, Smoky River Coalfield, Rocky Mountain Foothills, Alberta

b. **collotelinite** (Ct) showing some cell structure, associated with collodetrinite (Cd) and fusinite (Fu); 1.16%R_om; Lower Cretaceous Bickford Formation (Minnes Group), Peace River Coalfield, Rocky Mountain Foothills, northeastern British Columbia

c. homogeneous **collotelinite** (Ct) showing faint structure and fusinite (Fu); 1.15%R_om; No. 2 coal zone, Jurassic–Lower Cretaceous Mist Mountain Formation, Crowsnest Coalfield, Rocky Mountain Front Ranges, southeastern British Columbia

d. **pseudovitrinite** ? (Psv) showing characteristic slits, internal fractures and slightly elevated reflectance; 1.20%R_om; Lower Cretaceous Bickford Formation (Minnes Group), Peace River Coalfield, Rocky Mountain Foothills, northeastern British Columbia

e. **pseudovitrinite** (Psv) showing characteristic stepped grain boundaries and higher reflectance than collotelinite; 1.2%R_om; Lower Cretaceous Bickford Formation (Minnes Group), Peace River Coalfield, Rocky Mountain Foothills, northeastern British Columbia

f. **collotelinite** (Ct) showing cell structure with fine granular micrinite (Mi) inclusions; 1.22%R_om; Lower Cretaceous Gates Formation, Smoky River Coalfield, Rocky Mountain Foothills, Alberta

g. **collodetrinite** (Cd) with macrinite (Ma) and inertodetrinite (Id) inclusions; 1.16%R_om; No. 1 coal zone, Jurassic–Lower Cretaceous Mist Mountain Formation, Crowsnest Coalfield, Rocky Mountain Front Ranges, southeastern British Columbia

h. **collodetrinite** (Cd) with inertodetrinite (Id) and sporinite (Sp); 1.30%R_om; Mammoth Seam; Jurassic–Lower Cretaceous Mist Mountain Formation; Crowsnest Coalfield, Rocky Mountain Front Ranges, southeastern British Columbia

i. **collodetrinite** (Cd) groundmass with inertodetrinite (Id) and inclusions of mineral matter (black areas); 1.30%R_om; Balmer Seam, Jurassic–Lower Cretaceous Mist Mountain Formation, Crowsnest Coalfield, Rocky Mountain Front Ranges, southeastern British Columbia

j. **collodetrinite** (Cd) groundmass with inertodetrinite (Id), sporinite (Sp) and lens of semifusinite (Sf); 1.16%R_om; Jewel Seam, Lower Cretaceous Gates Formation, Cadomin-Luscar Coalfield, Rocky Mountain Foothills, Alberta

k. **collodetrinite** (Cd) with inertodetrinite (Id), semifusinite (Sf) and sporinite (Sp); 1.20%R_om; No. 2 coal zone, Jurassic-Lower Cretaceous Mist Mountain Formation, Crowsnest Coalfield, Rocky Mountain Foothills, southeastern British Columbia

l. **collodetrinite** (Cd) forms the groundmass for inertodetrinite (Id) and sporinite (Sp); 1.20%R_om; No. 2 coal zone, Jurassic–Lower Cretaceous Mist Mountain Formation, Crowsnest Coalfield, Rocky Mountain Front Ranges, southeastern British Columbia

PLATE 10

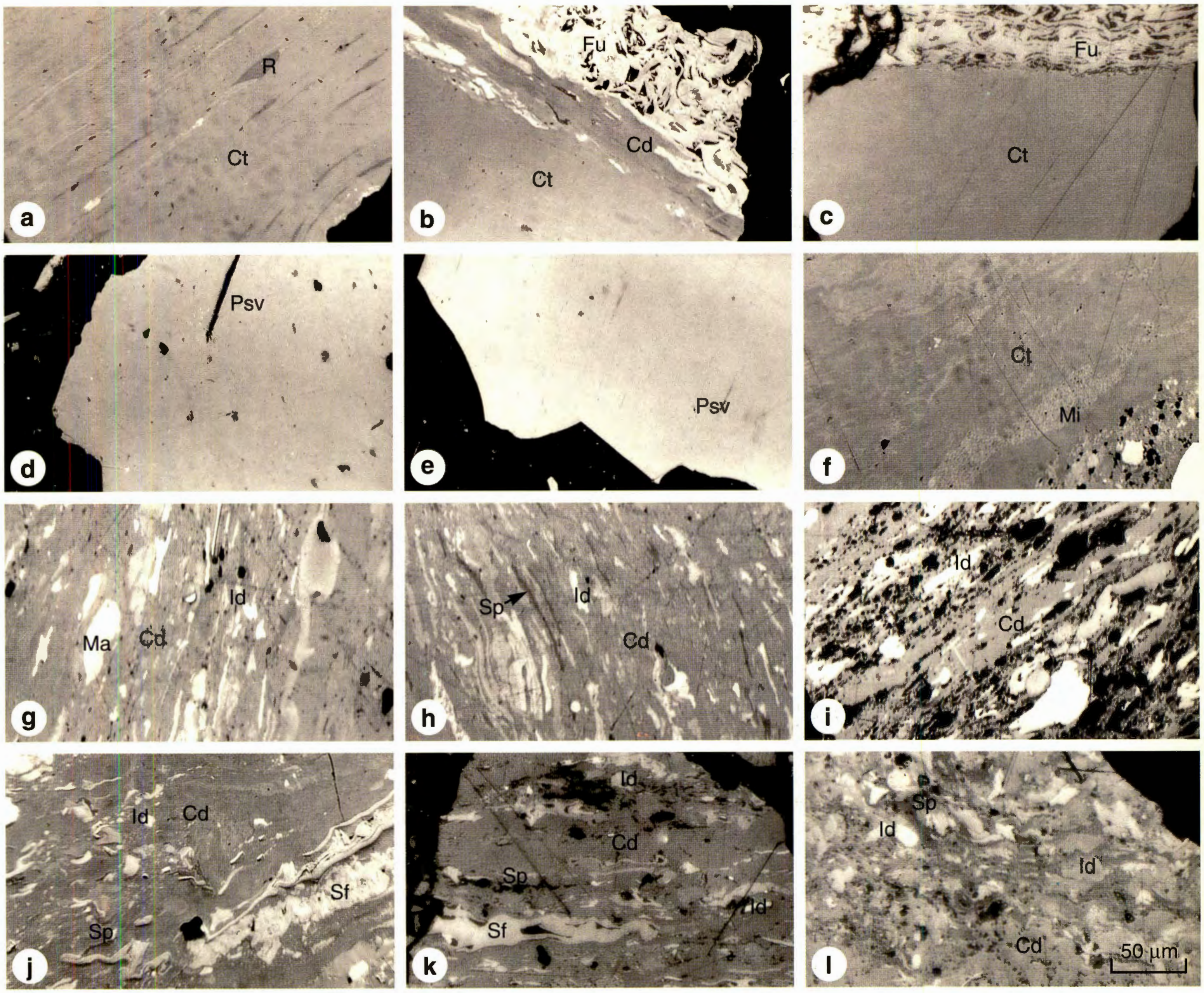
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PLATE 11

MEDIUM VOLATILE BITUMINOUS COALS
LIPTINITE MACERALS AND MINERAL MATTER

All photomicrographs except **b** and **h** were taken using white incident light and oil immersion objectives
magnification: same for all photos; see scale bar in photo **o**
coal rank: %R_om = mean maximum reflectance, in oil

a. **cutinite** (Cu) associated with corpogelinite (Cg) and collotelinite (Ct); 1.16%R_om; Jewel Seam, Lower Cretaceous Gates Formation, Cadomin-Luscar Coalfield, Rocky Mountain Foothills, Alberta

b. weakly fluorescing **cutinite** (Cu), **resinite** (R), **sporinite** (Sp) and **liptodetrinite** (Ld) in non-fluorescing collodetrinite; 1.12%R_om; unnamed seam in BP 81-13 well, Lower Cretaceous Gates Formation, Cadomin-Luscar Coalfield, Rocky Mountain Foothills, Alberta; (incident blue light; oil immersion)

c. **cutinite** (Cu) associated with collodetrinite (Cd) and inertodetrinite (Id); 1.16%R_om; Jewel Seam, Lower Cretaceous Gates Formation, Cadomin-Luscar Coalfield, Rocky Mountain Foothills, Alberta

d. **sporinite** (Sp), collodetrinite (Cd) inertodetrinite (Id) and semifusinite (Sf); 1.12%R_om; unnamed seam in BP well 81-13, Lower Cretaceous Gates Formation, Cadomin-Luscar Coalfield, Rocky Mountain Foothills, Alberta

e. **sporinite** (Sp), **cutinite** (Cu) and inertodetrinite (Id) in collodetrinite (Cd) groundmass; 1.3%R_om; Mammoth Seam, Jurassic–Cretaceous Mist Mountain Formation, Crowsnest Coalfield, East Kootenay coal district, southeastern British Columbia

f. **resinite** (R) in telinite (T) grading to collotelinite (Ct); 1.16%R_om; Jewel Seam, Lower Cretaceous Gates Formation, Cadomin-Luscar Coalfield, Alberta

g. **resinite** (R) in telinite (T) grading to collotelinite (Ct); 1.18%R_om; Lower Cretaceous Bickford Formation, Peace River Coalfield, northeastern British Columbia

h. fluorescing **liptodetrinite** (Ld) and **sporinite** (Sp) in vitrinite (V) groundmass; 1.12%R_om; unnamed seam, BP well 81-13, Lower Cretaceous Gates Formation, Cadomin-Luscar Coalfield, Alberta (incident blue light; oil immersion)

i. **sporinite** (Sp) and framboids of **pyrite** (Py) in collodetrinite (Cd); 1.18%R_om; Lower Cretaceous Bickford Formation, Peace River Coalfield, northeastern British Columbia

j. **calcite** (Ca) in inertinite-rich coal (In); 1.2%R_om; No. 3 coal zone, Jurassic–Cretaceous Mist Mountain Formation, Crowsnest Coalfield, southwestern Alberta

k. **calcite** (Ca) infilling open cell structure in fusinite (Fu); 1.2%R_om; No. 3 coal zone, Jurassic–Cretaceous Mist Mountain Formation, Crowsnest Coalfield, southwestern Alberta

l. **kaolinite** (K) in carbargillite interval; 1.2%R_om; No. 3 coal zone, Jurassic–Cretaceous Mist Mountain Formation, Crowsnest Coalfield, southwestern Alberta

m. **mineral matter** and micrinite (Mi) concretions in collodetrinite (Cd); 1.18%R_om; Lower Cretaceous Bickford Formation, Peace River Coalfield, northeastern British Columbia

n. **mineral matter** (Mm) with collotelinite (Ct) and funginite (Fg); 1.18%R_om; Lower Cretaceous Bickford Formation, Peace River Coalfield, northeastern British Columbia

o. **mineral matter** (Mm) in large concentrations in carbargillite interval, with collotelinite (Ct) lenses; 1.2%R_om; No. 3 coal zone, Jurassic–Cretaceous Mist Mountain Formation, Crowsnest Coalfield, southwestern Alberta

PLATE 11

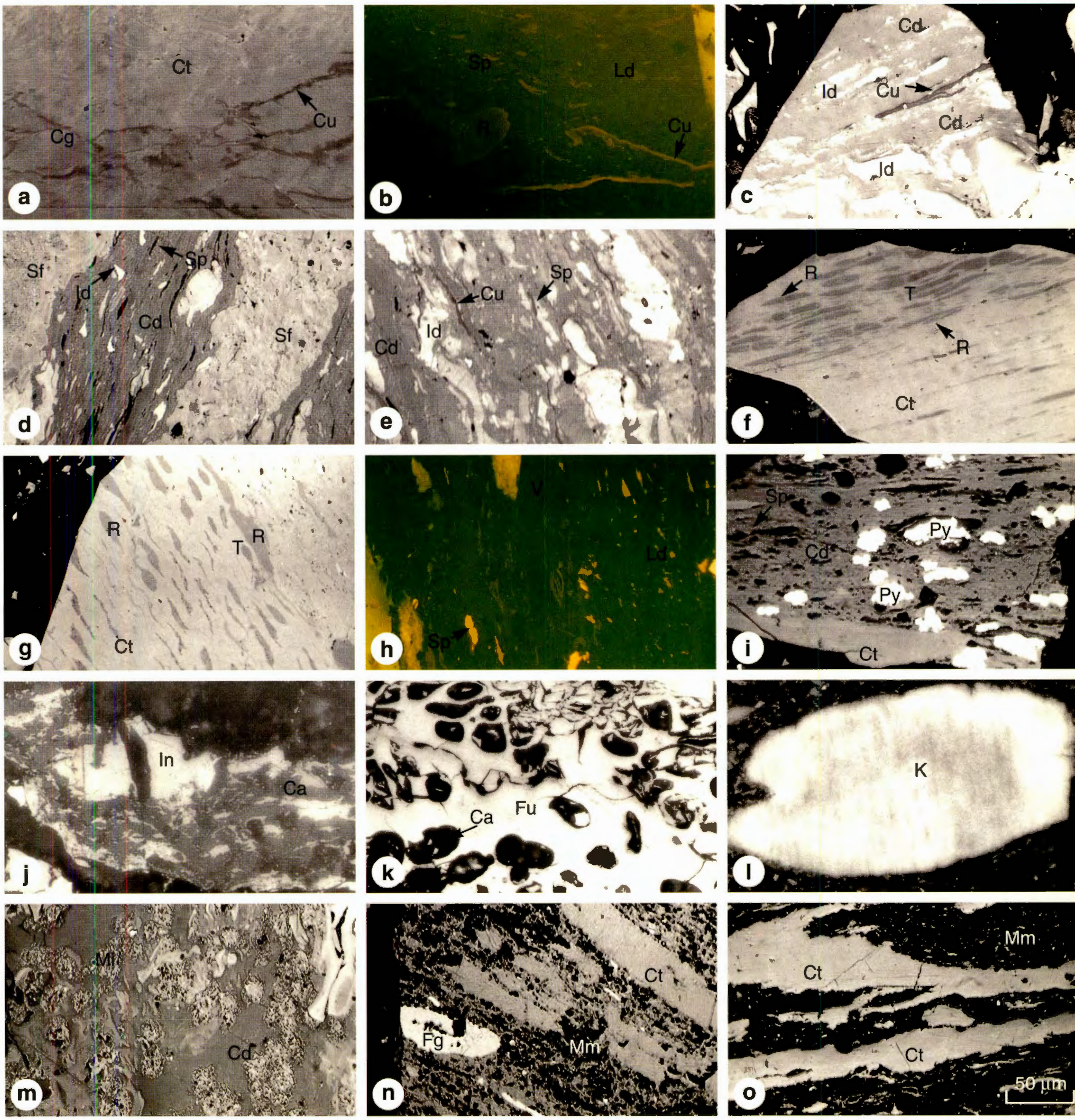

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PLATE 12

MEDIUM VOLATILE BITUMINOUS COALS
INERTINITE MACERALS

All photomicrographs were taken using white incident light and oil immersion objectives
magnification: same for all photos; see scale bar in photo **o**
coal rank: $\%R_om$ = mean maximum reflectance, in oil

a. **fusinite** with characteristic high reflectance and open cell luminae; 1.2$\%R_om$; Lower Cretaceous Bickford Formation, Peace River Coalfield, northeastern British Columbia

b. **fusinite** with bogen structure; 1.15$\%R_om$; Lower Cretaceous Bickford Formation, Peace River Coalfield, northeastern British Columbia

c. **semifusinite** (Sf) with **fusinite** (Fu); note the high relief of the fusinite; 1.16$\%R_om$; Jewel Seam, Lower Cretaceous Gates Formation, Smoky River Coalfield, Alberta

d. **semifusinite** with open cell structure; note the significantly lower reflectance compared to fusinite (in photo **a**); 1.2$\%R_om$; Lower Cretaceous Bickford Formation, Peace River Coalfield, northeastern British Columbia

e. **semifusinite** (Sf) with gelinite (G) infilling; 1.16$\%R_om$; No. 4 Seam, Lower Cretaceous Gates Formation, Smoky River Coalfield, Alberta

f. **semifusinite** (Sf) and **fusinite** (Fu); note the differences in relief and reflectivity; 1.22$\%R_om$; Seam No. 4, Lower Cretaceous Gates Formation, Smoky River Coalfield, Alberta

g. **semifusinite** (Sf) and collodetrinite (Cd) with **inertodetrinite** (Id); 1.2$\%R_om$; Lower Cretaceous Bickford Formation, Peace River Coalfield, northeastern British Columbia

h. **semifusinite** (Sf) from different sources showing differences in reflectance and morphology; 1.2$\%R_om$; No. 4 coal zone, Jurassic–Cretaceous Mist Mountain Formation, Crowsnest Coalfield, southwestern Alberta

i. **semifusinite** (Sf) transitional to **macrinite** (Ma) (?semimacrinite/gelovitrinite (Sm)); 1.2$\%R_om$; No. 3 coal zone, Jurassic–Cretaceous Mist Mountain Formation, Crowsnest Coalfield, southwestern Alberta

j. anisotropic **semifusinite** (Sf) viewed under partly crossed polars to show undulose extinction; 1.35$\%R_om$; No. 10 coal zone, Jurassic–Cretaceous Mist Mountain Formation, Crowsnest Coalfield, East Kootenay coal district; southeastern British Columbia

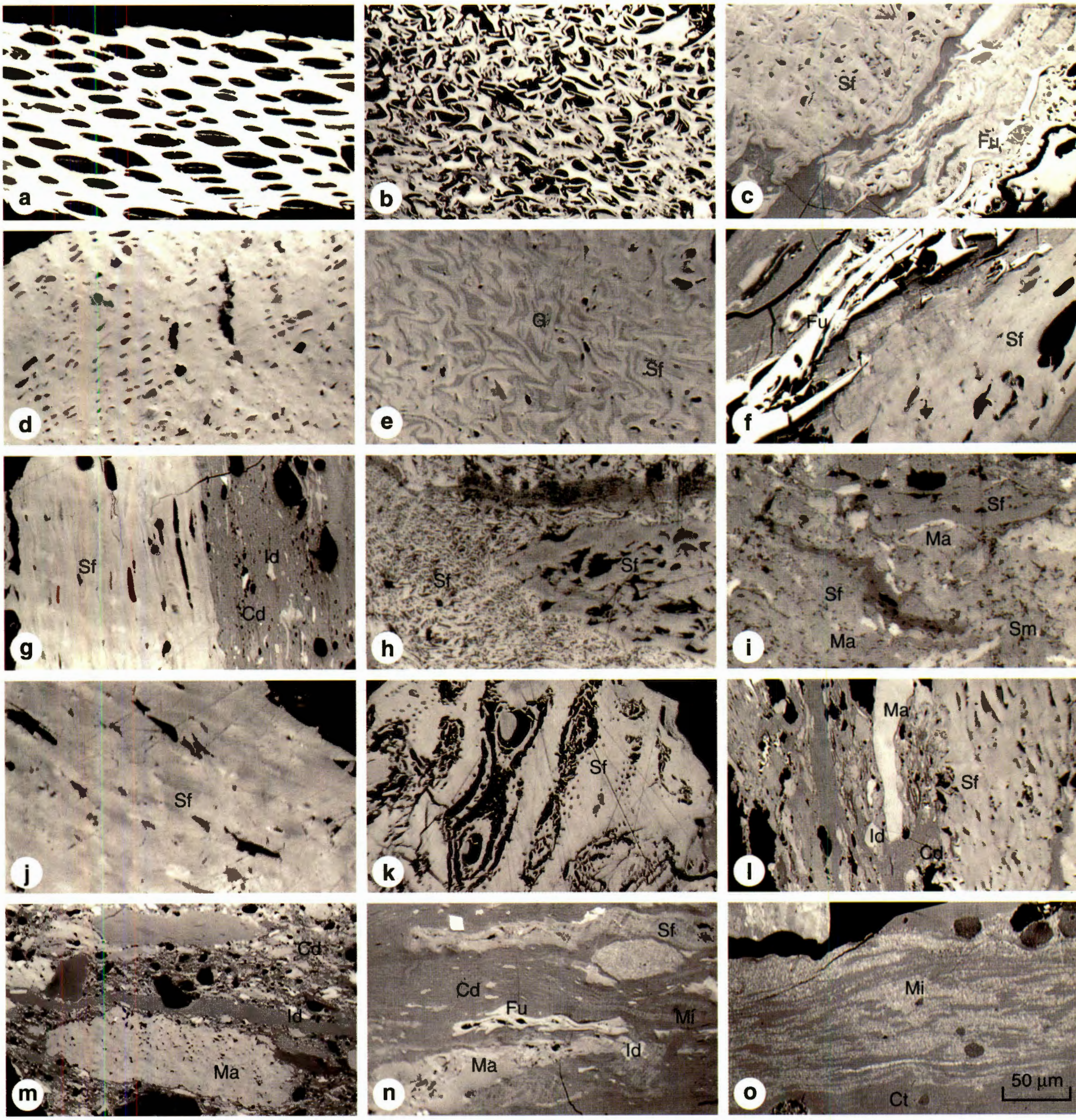
k. **semifusinite** (Sf); 1.22$\%R_om$; Seam 4, Lower Cretaceous Gates Formation, Smoky River Coalfield, northeastern British Columbia

l. **inertodetrinite** (Id) and **macrinite** (Ma) in collodetrinite (Cd) and semifusinite (Sf); 1.22$\%R_om$; Seam 4, Lower Cretaceous Gates Formation, Smoky River Coalfield, northeastern British Columbia

m. **macrinite** (Ma) with **inertodetrinite** (Id) and collodetrinite (Cd); 1.20$\%R_om$; Lower Cretaceous Gething Formation, Peace River Coalfield, northeastern British Columbia

n. various inertinites in collodetrinite (Cd): **fusinite** (Fu), **semifusinite** (Sf), **macrinite** (Ma), **micrinite?** (Mi) and **inertodetrinite** (Id); 1.16$\%R_om$; Lower Cretaceous Bickford Formation, Peace River Coalfield, northeastern British Columbia

o. **micrinite** (Mi) lenses in collotelinite (Ct); 1.20$\%R_om$; Lower Cretaceous Bickford Formation, Peace River Coalfield, northeastern British Columbia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REFERENCES: MEDIUM VOLATILE BITUMINOUS COALS OF CANADA

Bustin, R.M. (1982). The effects of shearing on the quality of some coals in the southeastern Canadian Cordillera. Canadian Institute of Mining and Metallurgy, Bulletin, V. 75: 76-83.

Bustin, R.M. and England, J.D. (1989). Timing of Organic Maturation (coalification) relative to thrust faulting in the southeastern Canadian Cordillera. International Journal of Coal Geology, V. 13: 327-339.

Cameron, A.R. (1972). Petrography of Kootenay coals in the upper Elk Valley and Crowsnest areas; Research Council of Alberta Information Series, No. 60: 31-45.

Cameron, A.R. (1984). Comparison of reflectance data for various macerals for coals of the Kootenay Group, southeastern British Columbia. In: Symposium on the Geology of the Rocky Mountain Coal; North Dakota Geological Society Proceedings 1984; Publication 84-1: 61-75.

Cameron, A.R. (1993). Coal, subchapter 6B. In: Sedimentary Cover of the Craton in Canada, D.F. Stott and J.D. Aitken (eds.). Geological Survey of Canada, Geology of Canada, No. 5: 563-598. (Also Geological Society of America, the Geology of North America, V. D-1.)

Cameron A.R. and Botham, J.C. (1966). Petrography and carbonization characteristics of some western Canadian coals. In: Coal Science, R.F. Gould (ed.). Advances in Chemistry Series 55, American Chemical Society, Washington, D.C.: 564-576.

Cameron, A.R. and Kalkreuth, W.D. (1982). Petrological characteristics of Jurassic-Cretaceous coals in the Foothills and Rocky Mountains of Western Canada. Proc. 5th Symposium on the Geology of Rocky Mountain Coal; Utah Geological and Mineralogical Survey, Bulletin 118: 163-167.

Grieve, D.A. (1993). Geology and rank distribution of the Elk Valley Coalfield, southeastern British Columbia (82G/15, 82J/2, 6,7,10). British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Survey Branch, Bulletin 82, 188 p.

Grieve, D.A. (1991). Biaxial vitrinite reflectance in coals of the Elk Valley Coalfield, southeastern British Columbia, Canada. International Journal of Coal Geology, V. 19: 185-200.

Hacquebard, P.A. (1977). Rank of coal as an index of organic metamorphism for oil and gas in Alberta; Chapter 3. In: The .origin and migration of petroleum in the Western Canada Sedimentary Basin, Alberta, G. Deroo, T.G. Powell, B. Tissot and R.G. McCrossan (eds.). Geological Survey of Canada, Bulletin 262: 11-22.

Hacquebard, P.A. and Donaldson, J.R. (1974). Rank studies in the Rocky Mountains and Inner Foothills Belt, Canada. In: Carbonaceous materials as indicators of metamorphism, R.R. Dutcher, P.A. Hacquebard J.M. Schopf and J.A. Simon (eds.). Geological Society of America, Special Paper 153: 75-94.

Hacquebard, P.A. and Cameron, A.R. (1989). Distribution and coalification patterns in Canadian bituminous coals and anthracites. International Journal of Coal Geology, V. 13, 207-260.

Hughes, J.D. and Cameron, A.R. (1985). Lithology, depositional setting and coal rank-depth relationships in the Jurassic-Cretaceous Kootenay Group at Mount Allan, Cascade coal basin, Alberta. Geological Survey of Canada, Paper 81-11, 41 p.

Kalkreuth, W.D. (1982). Rank and petrographic composition of selected Jurassic-Lower Cretaceous coals from British Columbia, Canada. Bulletin of Canadian Petroleum Geology, V. 30, p.112-131.

Kalkreuth, W.D. and McMechan, M.E. (1984). Regional patterns of thermal maturation as determined from coal rank studies, Rocky Mountain Foothills and Front Ranges north of Grande Cache, Alberta - implications for petroleum exploration. Bulletin of Canadian Petroleum Geology, V. 32: 249-271.

Kalkreuth, W.D. and Leckie, D.E. (1989). Sedimentological and Petrological characteristics of Canadian Strandplain coals: a model for coal accumulation from the North American Western Interior Seaway. International Journal of Coal Geology, V. 12: 381-324.

Kalkreuth, W.D., Langenberg, W. and McMechan, M. (1989). Regional coalification patterns of Lower Cretaceous coal-bearing strata, Rocky Mountain Foothills and Foreland, Canada-Implications for future exploration. International Journal of Coal Geology, V. 13: 261-302.

Kalkreuth, W.D., Marchioni, D.L., Calder, J.H., Lamberson, M.N., Naylor, R.D. and Paul, J. (1991). The relationship between coal petrography and depositional environments from selected coal basins in Canada. International Journal of Coal Geology, V. 19: 21-76.

Kilby, W.E. (1991). Vitrinite reflectance measurement - some technique enhancements and relationships. International Journal of Coal Geology, V. 19: 201-218.

Marchioni, D.L. (1983). The detection of weathering in coal by petrographic, rheological and chemical methods. International Journal of Coal Geology, V. 2: 231-259.

Pearson, D.E. (1980). The quality of Western Canadian Coking coal. Canadian Institute of Mining and Metallurgy, Bulletin: 73: 1-15.

Pearson, D.E. and Grieve, D.A. (1985). Rank distribution and coalification pattern, Crowsnest coalfield, British Columbia, Canada. Proc. 9th International Congress of Carboniferous Stratigraphy and Geology, Champagne-Urbana, Illinois, May 1979, Compte Rendu V. 4: 600-608.

Pearson, D.E and Pearson, J.S. (1983). The reactivity of inertinites in coking coals from British Columbia (abstract). Canadian Institute of Mining and Metallurgy, Bulletin, V. 76: 52.

LOW VOLATILE BITUMINOUS COAL

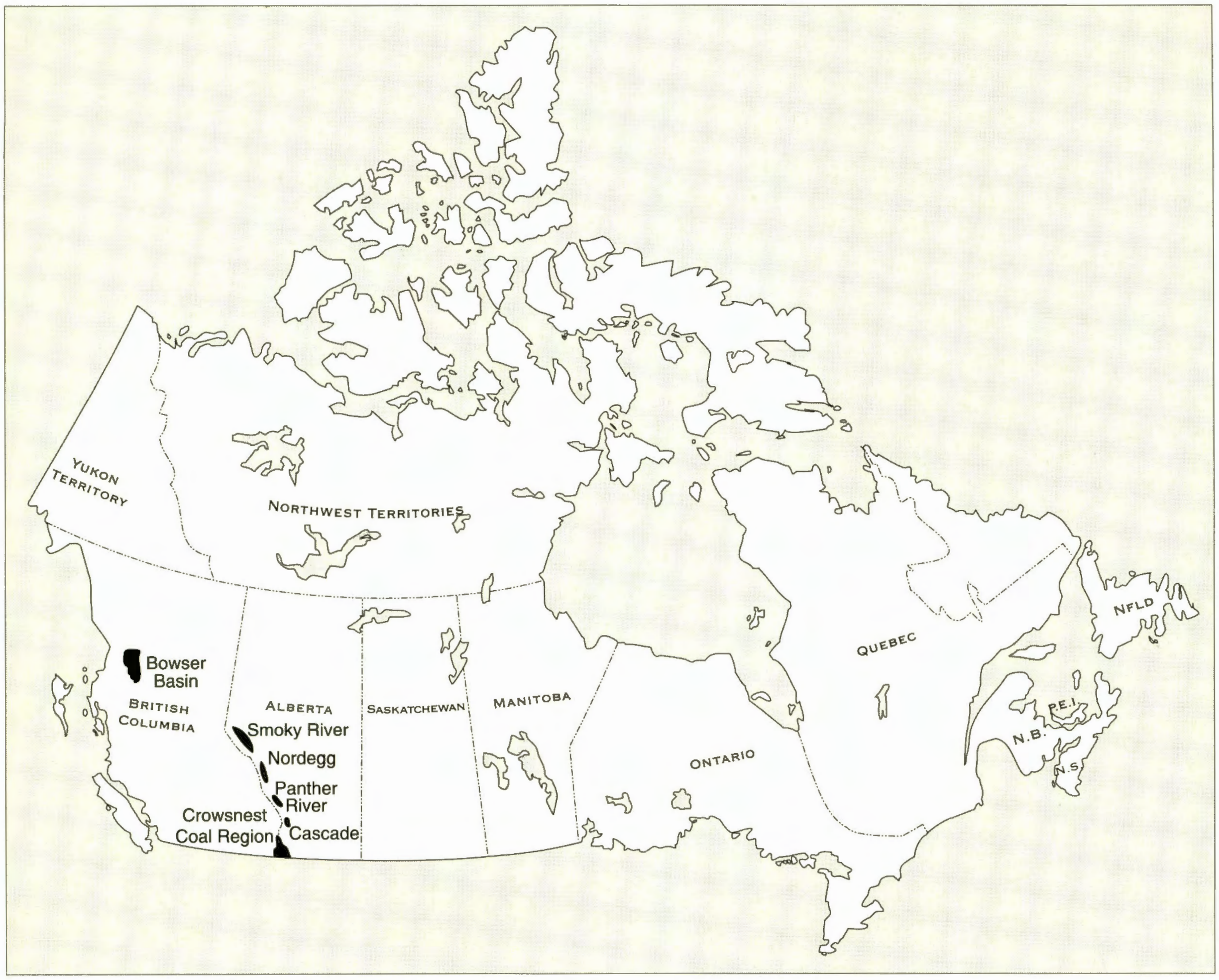


Figure 6a. Low volatile bituminous coal deposits

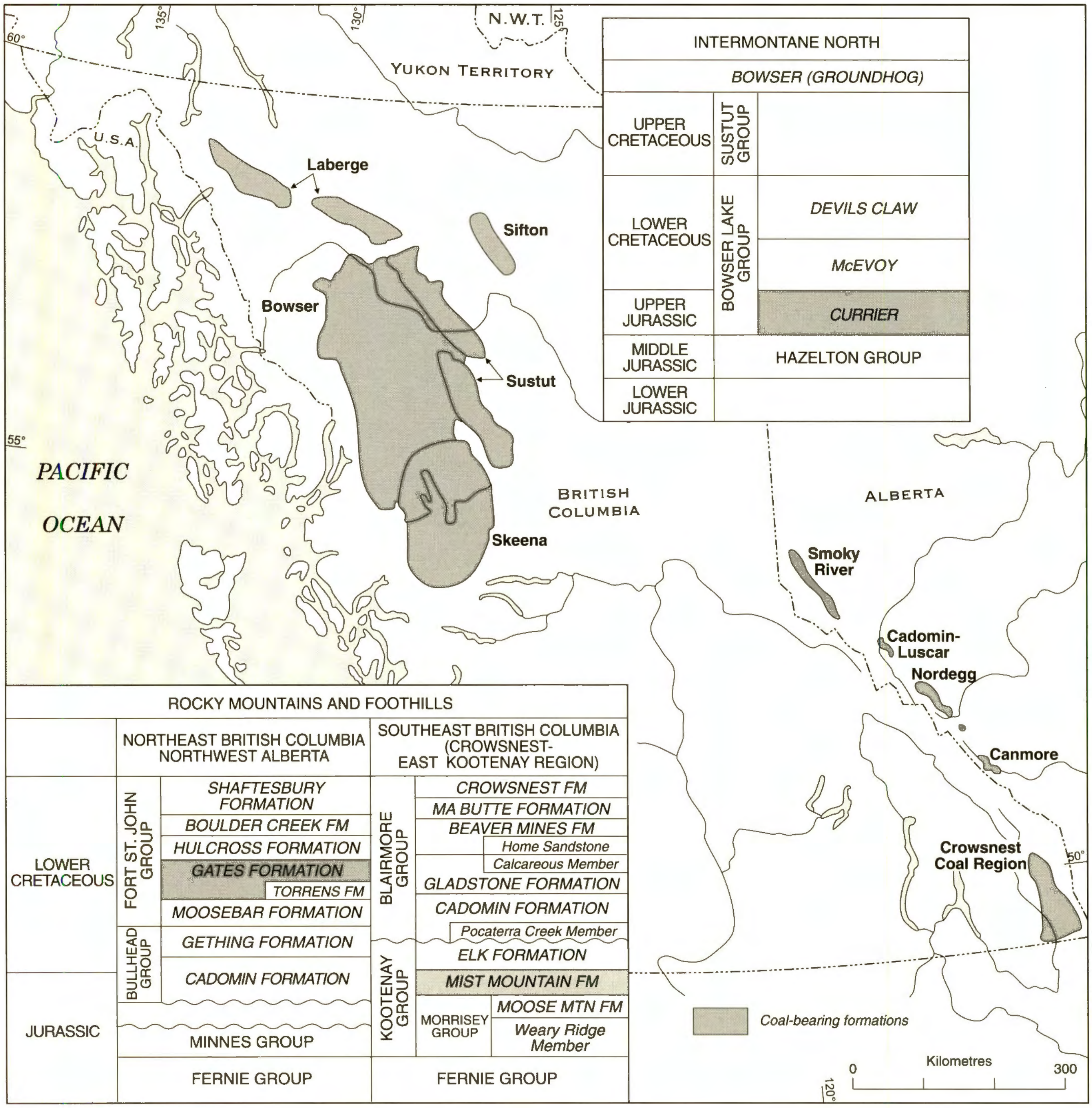


Figure 6b. Coalfields and coal-bearing formations of western Canada

PLATE 13

LOW VOLATILE BITUMINOUS COALS
ALL MACERALS

All photomicrographs were taken using white incident light and oil immersion objectives
magnification: same for all photos; see scale bar in photo **o**
coal rank: $\%R_om$ = mean maximum reflectance, in oil

a. **collotelinite** (Ct) (?pseudovitrinite) with **micrinite** (Mi) lenses; 1.43$\%R_om$; No.10 Seam, Jurassic–Cretaceous Mist Mountain Formation, Crowsnest Coalfield, East Kootenay coal district, southeastern British Columbia

b. **collodetrinite** (Cd) groundmass with inclusions of **inertodetrinite** (Id) and **macrinite** (Ma); 1.52$\%R_om$; Jurassic–Cretaceous Mist Mountain Formation, Crowsnest Coalfield, East Kootenay coal district, southeastern British Columbia

c. high density **micrinite** (Mi) bands intercalated with thin **collotelinite** (Ct) bands; 1.62$\%R_om$; No. 4 Seam, Lower Cretaceous Gates Formation, Smoky River Coalfield, Alberta

d. **fusinite** (Fu) containing dispersed **funginite** (Fg); 1.62$\%R_om$; No. 4 Seam, Lower Cretaceous Gates Formation, Smoky River Coalfield, Alberta

e. **fusinite** with open cell lumina; 1.62$\%R_om$; No. 4 Seam, Lower Cretaceous Gates Formation, Smoky River Coalfield, Alberta

f. **macrinite** (Ma) and **inertodetrinite** (Id) embedded in **collodetrinite** (Cd); 1.62$\%R_om$; No. 4 seam, Lower Cretaceous Gates Formation, Smoky River Coalfield, Alberta

g. **semifusinite** (Sf) with **fusinite** (Fu) and **collodetrinite** (Cd), 1.43$\%R_om$; No.10 Seam, Jurassic–Cretaceous Mist Mountain Formation, Crowsnest Coalfield, East Kootenay coal district, British Columbia

h. **fusinite** (Fu) with **semifusinite** (Sf), **collodetrinite** (Cd) and **inertodetrinite** (Id); 1.43$\%R_om$; No.10 Seam, Jurassic–Cretaceous Mist Mountain Formation, Crowsnest Coalfield, East Kootenay coal district, southeastern British Columbia

i. **fusinite** (Fu) with large **inertodetrinite** (Id) fragments embedded in **collodetrinite** (Cd); 1.43$\%R_om$; No.10 seam, Jurassic–Cretaceous Mist Mountain Formation, Crowsnest Coalfield, East Kootenay coal district, southeastern British Columbia

j. **semifusinite** (Sf) impregnated by **carbonate** (Ca) (white light); 1.43$\%R_om$; No.10 Seam, Jurassic–Cretaceous Mist Mountain Formation, Crowsnest Coalfield, East Kootenay coal district, southeastern British Columbia

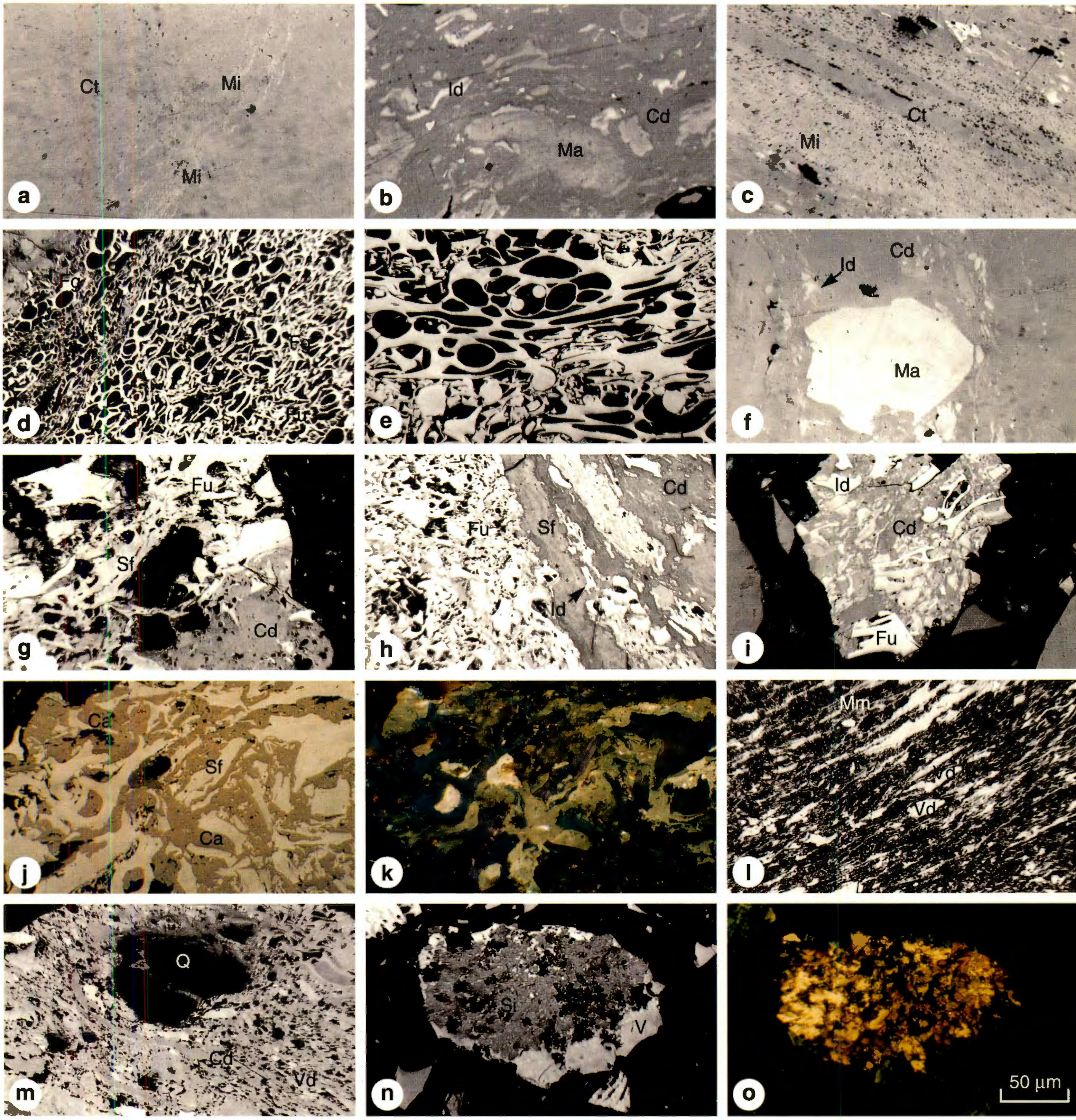
k. same field as **j**, crossed polars

l. **mineral matter** (clay minerals) (Mm) with lenses and grains of **vitrodetrinite** (Vd) embedded in it; 1.62$\%R_om$; No. 4 Seam, Lower Cretaceous Gates Formation, Smoky River Coalfield, Alberta

m. **quartz** grains (Q) in **collodetrinite** (Cd) and **vitrodetrinite** (Vd); 1.62$\%R_om$; No. 4 Seam, Lower Cretaceous Gates Formation, Smoky River Coalfield, Alberta

n. **carbonate** mineral (**?siderite**), (Si) associated with **vitrinite** (V)(**?collotelinite**);1.43$\%R_om$; No.10 Seam, Jurassic–Cretaceous Mist Mountain Formation, Sparwood, British Columbia

o. Same field as **n**, crossed polars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k
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Mm
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m
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Cd
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n
Si
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o
50 µm

REFERENCES: LOW VOLATILE BITUMINOUS COALS OF CANADA

Bustin, R.M. (1982). The effects of shearing on the quality of some coals in the southeastern Canadian Cordillera; Canadian Institute of Mining and Metallurgy, Bulletin, V. 75: 76-83.

Bustin, R.M. and England, J.D. (1989). Timing of organic maturation (coalification) relative to thrust faulting in the southeastern Canadian Cordillera. International Journal of Coal Geology, V. 13: 327-339

Cameron, A.R. (1972). Petrography of Kootenay coals in the upper Elk Valley and Crowsnest areas; Research Council of Alberta Information Series, No. 60: 31-45.

Cameron, A.R. (1984). Comparison of reflectance data for various macerals from coals of the Kootenay Group, southeastern British Columbia. In: Symposium on the Geology of the Rocky Mountain Coal. North Dakota Geological Society Proceedings 1984; Publication 84-1: 61-75.

Cameron, A.R. (1993). Coal, subchapter 6B. In: Sedimentary Cover of the Craton in Canada, D.F. Stott and J.D. Aitken (eds.). Geological Survey of Canada, Geology of Canada, No. 5: 563-598. (Also Geological Society of America, the Geology of North America, V. D-1.)

Cameron A.R. and Botham, J.C. (1966). Petrography and carbonization characteristics of some western Canadian coals. In: Coal Science, R.F. Gould (ed.). Advances in Chemistry Series 55, American Chemical Society, Washington, D.C., p. 564-576.

Cameron, A.R. and Kalkreuth, W.D. (1982). Petrological characteristics of Jurassic-Cretaceous coals in the Foothills and Rocky Mountains of Western Canada. Proc. 5th Symposium on the Geology of Rocky Mountain Coal; Utah Geological and Mineralogical Survey, Bulletin 118: 163-167.

Grieve, D.A. (1993). Geology and rank distribution of the Elk Valley Coalfield, southeastern British Columbia (82G/15, 82J/2, 6,7,10). British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Survey Branch, Bulletin 82, 188 p.

Hacquebard, P.A. (1977). Rank of coal as an index of organic metamorphism for oil and gas in Alberta; Chapter 3. In: The Origin and Migration of Petroleum in the Western Canada Sedimentary Basin, Alberta, G. Deroo, T.G. Powell, B. Tissot and R.G. McCrossan (eds.). Geological Survey of Canada, Bulletin 262: 11-22.

Hacquebard, P.A. and Donaldson, J.R. (1974). Rank studies in the Rocky Mountains and Inner Foothills Belt, Canada. In: Carbonaceous Materials as Indicators of Metamorphism, R.R. Dutcher, P.A. Hacquebard, J.M. Schopf and J.A. Simon (eds.). Geological Society of America, Special Paper 153: 75-94.

Hacquebard, P.A. and Cameron, A.R. (1989). Distribution and coalification patterns in Canadian bituminous coals and anthracites. International Journal of Coal Geology, V. 13, 207-260.

Hughes, J.D. and Cameron, A.R. (1985). Lithology, depositional setting and coal rank-depth relationships in the Jurassic-Cretaceous Kootenay Group at Mount Allan, Cascade coal basin, Alberta. Geological Survey of Canada, Paper 81-11, 41 p.

Kalkreuth, W.D. (1982). Rank and petrographic composition of selected Jurassic-Lower Cretaceous coals from British Columbia, Canada. Bulletin of Canadian Petroleum Geology, V. 30: 112-131.

Kalkreuth, W.D. and McMechan, M.E. (1984). Regional patterns of thermal maturation as determined from coal rank studies, Rocky Mountain Foothills and Front Ranges north of Grande Cache, Alberta - implications for petroleum exploration. Bulletin of Canadian Petroleum Geology, V. 32: 249-271.

Kalkreuth, W.D. and Leckie, D.E. (1989). Sedimentological and petrological characteristics of Canadian Strandplain coals: a model for coal accumulation from the North American Western Interior Seaway. International Journal of Coal Geology, V. 12: 381-324.

Kalkreuth, W.D., Marchioni, D.L., Calder, J.H., Lamberson, M.N., Naylor, R.D. and Paul, J. (1991). The relationship between coal petrography and depositional environments from selected coal basins in Canada. International Journal of Coal Geology, V. 19: 21-76.

Kalkreuth, W.D., Langenberg, W. and McMechan, M. (1989). Regional coalification patterns of Lower Cretaceous coal-bearing strata, Rocky Mountain Foothills and Foreland, Canada - Implications for future exploration. International Journal of Coal Geology, V. 13: 261-302.

Kilby, W.E. (1991). Vitrinite reflectance measurement - some technique enhancements and relationships. International Journal of Coal Geology, V. 19: 201-218.

Langenberg, W. and Kalkreuth, W.D. (1991). Reflectance anisotropy and syndepositional coalification of the Jewel Seam in the Cadomin area, Alberta, Canada. International Journal of Coal Geology, V. 19: 303-318.

Marchioni, D.L. (1983). The detection of weathering in coal by petrographic, rheological and chemical methods. International Journal of Coal Geology, V. 2: 231-259.

Pearson, D.E. (1980). The quality of western Canadian coking coal. Canadian Institute of Mining and Metallurgy, Bulletin: 73: 1-15.

Pearson, D.E. and Grieve, D.A. (1985). Rank distribution and coalification pattern, Crowsnest coalfield, British Columbia, Canada. Proc. 9th International Congress of Carboniferous Stratigraphy and Geology, Champagne-Urbana, Illinois, June 1989, V. 4: 600-608.

Pearson, D.E and Pearson, J.S. (1983). The reactivity of inertinites in coking coals from British Columbia (abstract). Canadian Institute of Mining and Metallurgy, Bulletin, V. 76: 52.

SEMIANTHRACITES AND ANTHRACITES

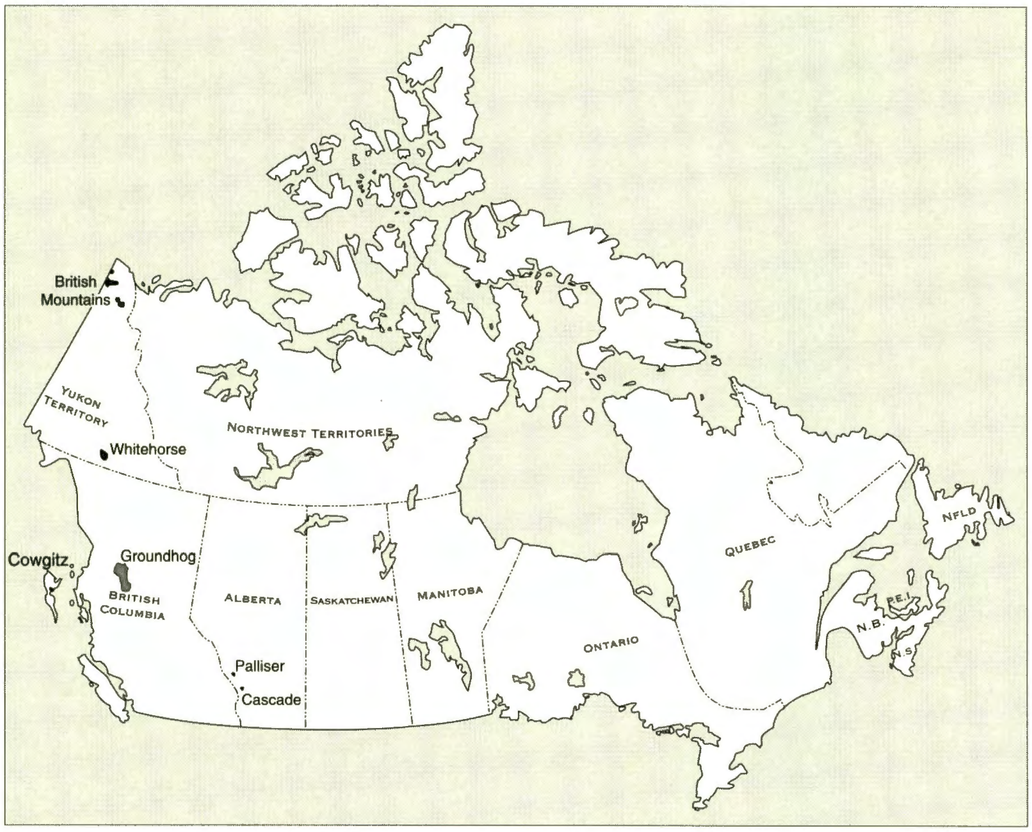


Figure 7a. Anthracite and semianthracite deposits

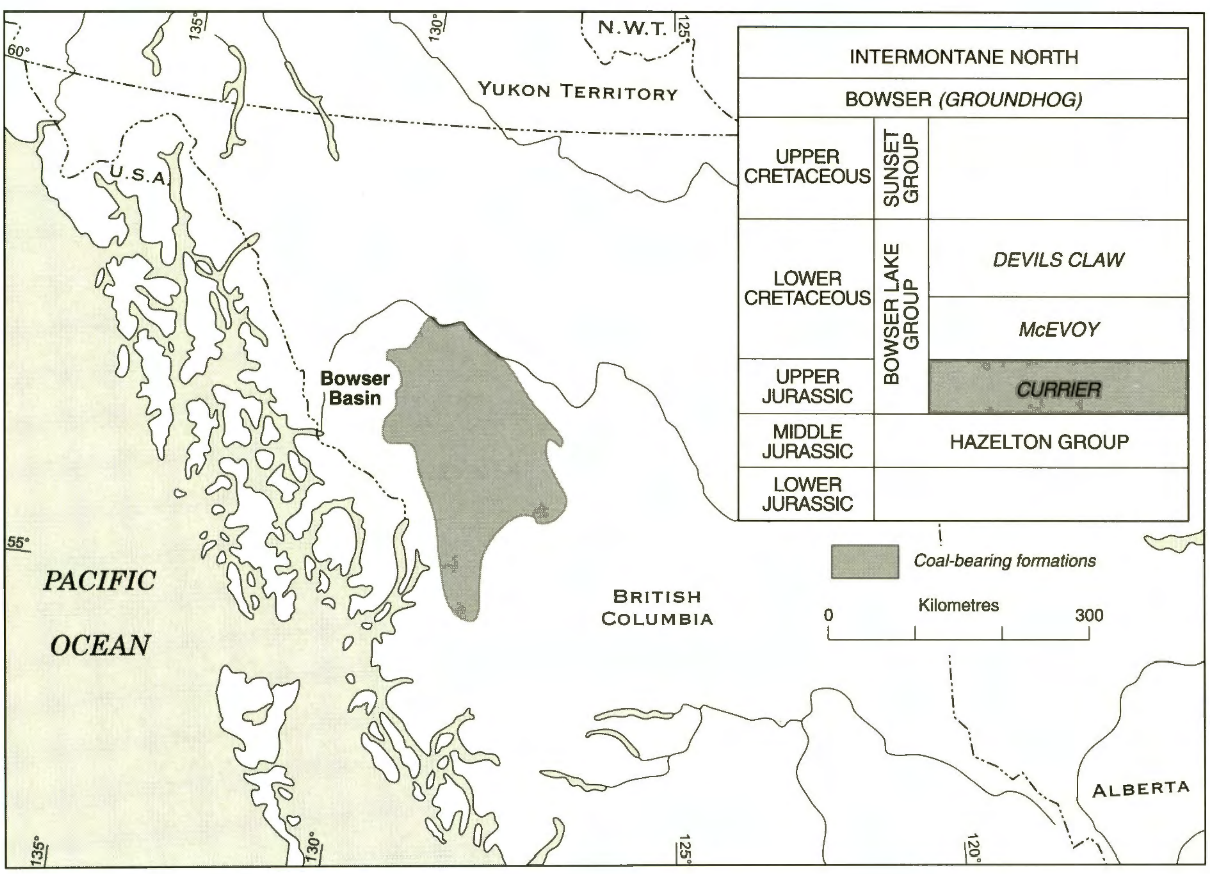
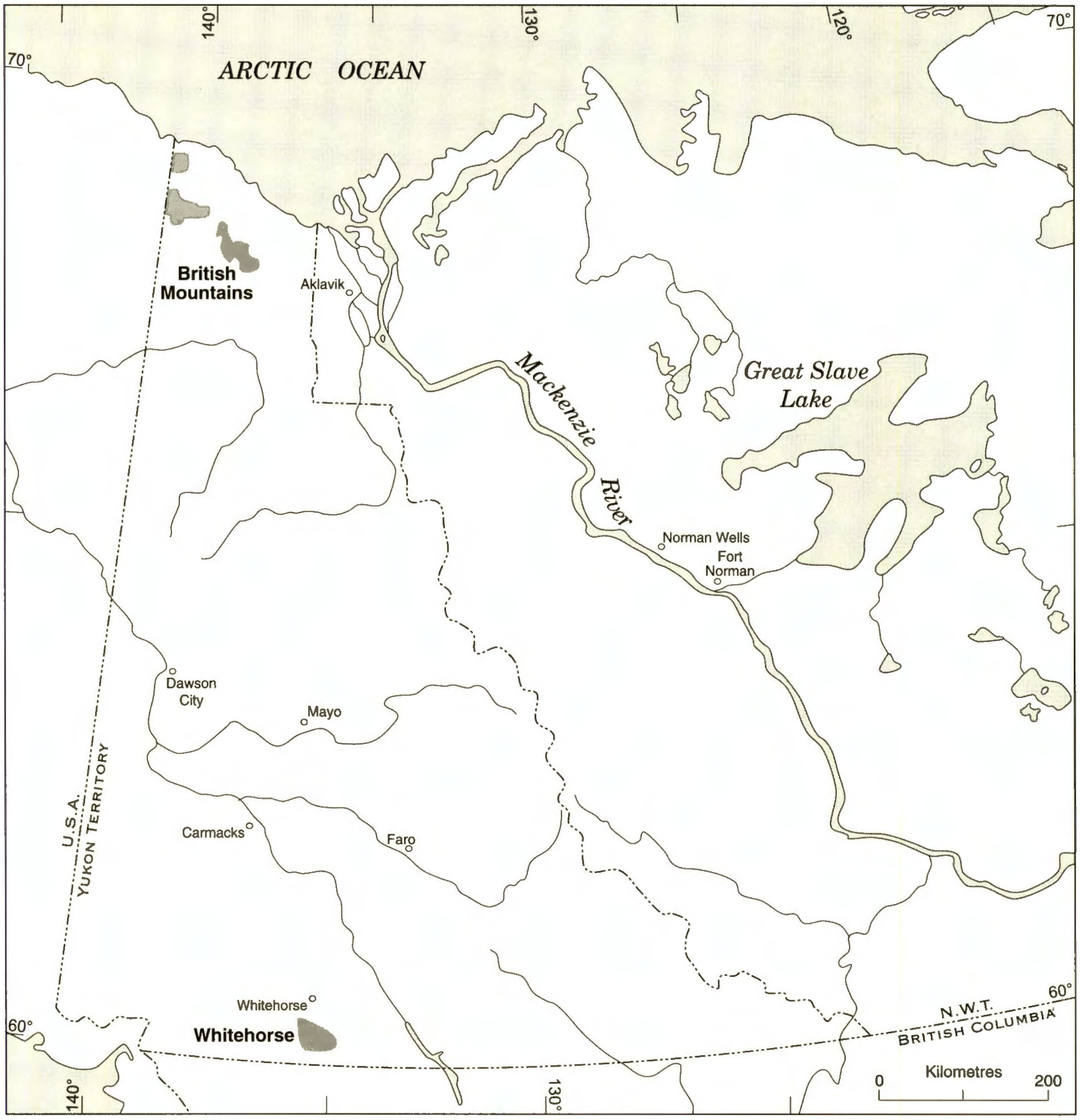


Figure 7b. Coal-bearing formations of interior British Columbia



BRITISH MOUNTAINS - HOIDAHL DOME	
JURASSIC-LOWER CRETACEOUS	*KINGAK FORMATION*
LOWER CARBONIFEROUS	*KAYAK FORMATION*
	KEKIKTUK FORMATION
SILURIAN	

Figure 7c. Coal-bearing formations of northern Yukon Territory

PLATE 14

SEMIANTHRACITES AND ANTHRACITES ALL MACERALS

All photomicrographs were taken using white incident light and oil immersion objectives
magnification: same for all photos; see scale bar in photo **p**
coal rank: $\%R_om$ = mean maximum reflectance, in oil

a. laminae of **collotelinite** (Ct) and **collodetrinite** (Cd); semianthracite ($2.94\%R_om$), Lower Carboniferous Kayak Formation, Hoidahl Dome region, Yukon Territory

b. **collodetrinite** (Cd) and **inertodetrinite** (Id); semianthracite ($2.0\%R_om$), Jurassic–Cretaceous Mist Mountain Formation, Cascade Coalfield, Alberta

c. **corpogelinite** (Cg) and **gelinite** (G) mottled with **inertodetrinite**; semianthracite ($2.0\%R_om$), Jurassic–Cretaceous Mist Mountain Formation, Cascade Coalfield, Alberta

d. **mineral matter** (Mm) impregnated with **gelovitrinite** (Vg) and **collodetrinite** (Cd); semianthracite ($2.0\%R_om$), Jurassic–Cretaceous Mist Mountain Formation, Cascade Coalfield, Alberta

e. **collodetrinite** (Cd) with inclusions of **semifusinite** (Sf); semianthracite ($2.83\%R_om$), Lower Cretaceous Currier Formation, Groundhog Coalfield, British Columbia

f. **collodetrinite** (Cd) with inclusions of **mineral matter** (Mm); semianthracite ($2.83\%R_om$), Lower Cretaceous Currier Formation, Groundhog Coalfield, British Columbia

g. **pyrite** (Py) framboids in **collotelinite** (Ct); anthracite ($3.04\%R_om$), Lower Cretaceous Currier Formation, Groundhog Coalfield, British Columbia

h. **collotelinite** (Ct) with **fusinite** (F) and **semifusinite** (Sf); anthracite ($3.04\%R_om$), Lower Cretaceous Currier Formation, Groundhog Coalfield, British Columbia

i. **collodetrinite** (Cd) with inclusions of **inertodetrinite** (Id) and **?semifusinite** (Sf); anthracite ($3.04\%R_om$), Lower Cretaceous Currier Formation, Groundhog Coalfield, British Columbia

j. tectonic folds in **semifusinite** (Sf); anthracite ($3.89\%R_om$), Lower Cretaceous Currier Formation, Groundhog Coalfield, British Columbia

k. **fusinite**, showing positive relief; semianthracite ($2.99\%R_om$), Lower Carboniferous Kayak Formation, Hoidahl Dome region, Yukon Territory

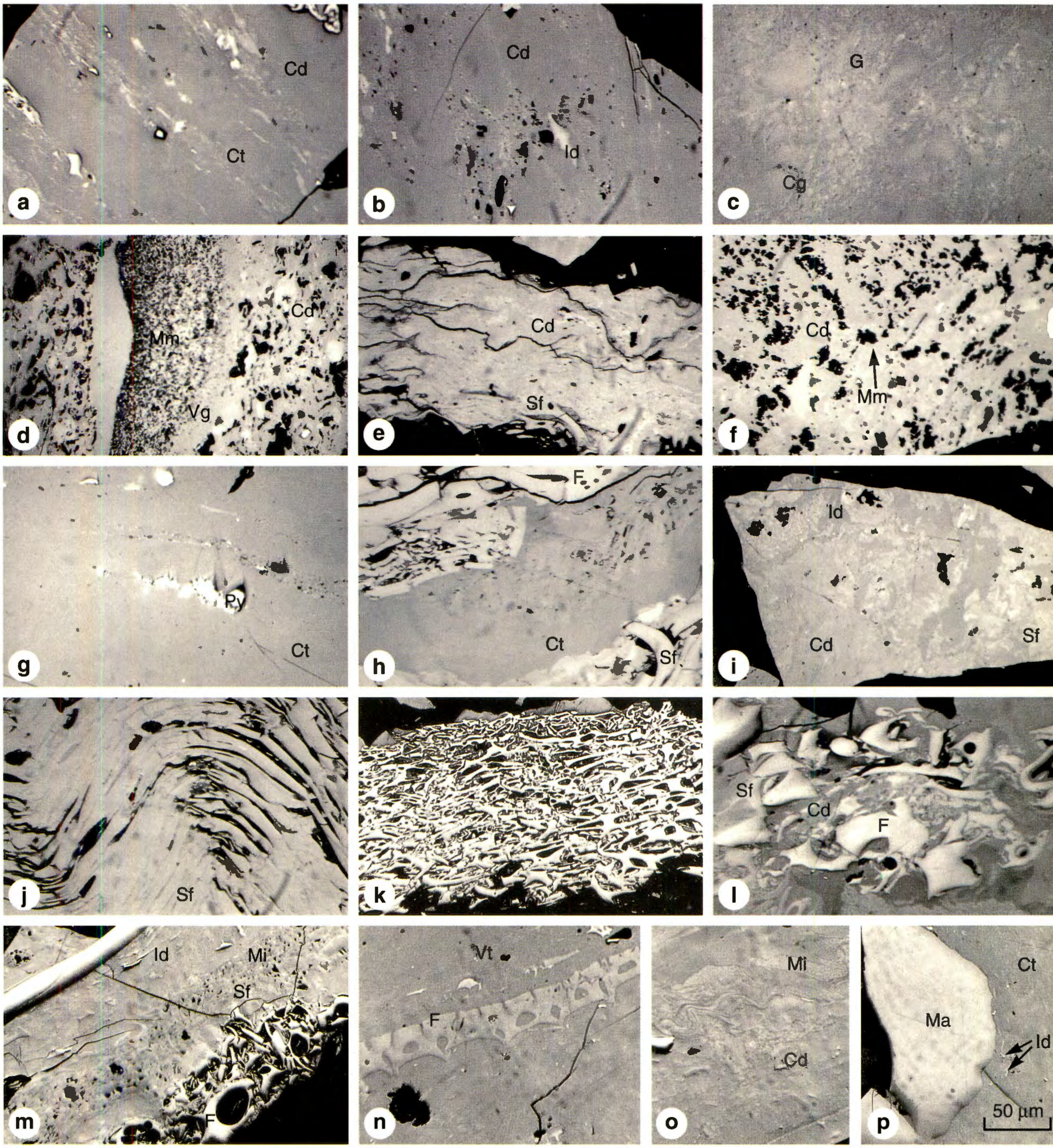
l. **fusinite** (F), showing positive relief, and **semifusinite** (Sf) in **collodetrinite** (Cd); semianthracite ($2.88\%R_om$), Lower Carboniferous Kayak Formation, Hoidahl Dome region, Yukon Territory

m. **semifusinite** (Sf) and **fusinite** (F) with traces of **micrinite** (Mi) and **inertodetrinite** (Id); semianthracite ($3.00\%R_om$), Lower Carboniferous Kayak Formation, Hoidahl Dome region, Yukon Territory

n. **fusinite** (F) showing high relief, in **telovitrinite** (Vt); semianthracite ($2.99\%R_om$), Lower Carboniferous Kayak Formation, Hoidahl Dome region,Yukon Territory

o. **micrinite** (Mi) lenses and inclusions in **collodetrinite** (Cd); semianthracite ($3.00\%R_om$), Lower Carboniferous Kayak Formation, Hoidahl Dome region, Yukon Territory

p. **macrinite** (Ma) and **inertodetrinite** (arrows) associated with **collotelinite** (Ct); semi-anthracite ($2.94\%R_om$), Lower Carboniferous Kayak Formation, Hoidahl Dome region, Yukon Territory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REFERENCES: ANTHRACITES AND SEMIANTHRACITES OF CANADA

Bustin, R.M. (1984). Coalification levels and their significance in the Groundhog Coalfield, north-central British Columbia. International Journal of Coal Geology, V. 4: 21-44.

Bustin, R.M. and England, J.D. (1989). Timing of organic maturation (coalification) relative to thrust faulting in the southeastern Canadian Cordillera. International Journal of Coal Geology, V. 13: 327-339

Bustin, R.M. and Moffat, I. (1989). Semianthracite, anthracite and meta-anthracite in the Central Canadian Cordillera: their geology, characteristics and coalification history. International Journal of Coal Geology, V. 13: 303-326.

Cameron, A.R. (1993). Coal, subchapter 6B. In: Sedimentary Cover of the Craton in Canada, D.F. Stott and J.D. Aitken (eds.). Geological Survey of Canada, Geology of Canada, No. 5: 563-598. (Also Geological Society of America, the Geology of North America, V. D-1.)

Cameron, A.R., Boonstra, C. and Pratt, K.C. (1988). Compositional characteristcs of anthracitic coals in the Hoidahl Dome area, northern Yukon Territory. In: Current Research, Part D, Geological Survey of Canada, Paper 88-1D, 67-74.

Cameron, A.R., Norris, D.K. and Pratt, K.C. (1986). Rank and other compositional data on coals and carbonaceous shales of the Kayak Formation, northern Yukon Territory. Geological Survey of Canada, Paper 86-18: 665-670.

Cameron, A.R., Potter, J. and Goodarzi, F. (1994). Coal and oil shale of Early Carboniferous age in northern Canada: Significance for paleoenvironmental and paleoclimatic interpretations. Palaeogeography, Palaeoclimatology and Palaeoecology, V. 106, 35-155.

Hacquebard, P.A. and Donaldson, J.R. (1974). Rank studies in the Rocky Mountains and Inner Foothills Belt, Canada. In: Carbonaceous Materials as Indicators of Metamorphism, R.R. Dutcher, P.A. Hacquebard, J.M. Schopf and J.A. Simon (eds.). Geological Society of America, Special Paper 153: 75-94.

Hacquebard, P.A. and Cameron, A.R. (1989). Distribution and coalification patterns in Canadian bituminous coals and anthracites. International Journal of Coal Geology, V. 13, 207-260.

Hughes, J.D. and Cameron, A.R. (1985). Lithology, depositional setting and coal rank-depth relationships in the Jurassic-Cretaceous Kootenay Group at Mount Allan, Cascade coal basin, Alberta. Geological Survey of Canada, Paper 81-11, 41 p.

PLATE 15

CARBONIZATION RESIDUES

All photomicrographs were taken using white incident light under partly crossed polars and oil immersion objectives
magnification: scale in photo **b** applies to all except photos **a**, **k** and **m**; scale for these is in photo **a**
coke quality information: CBI = Composition Balance Index; CSI = Coke Strength Index StI = Coke Stability Index; FSI = Free Swelling Index
coke textures: based on classification of Grint and Marsh (1981)

a to e are cokes from medium volatile bituminous coal (VR_om: 1.27%), Lower Cretaceous Gates Formation, Peace River Coalfield, northeastern British Columbia; CBI:1.26, CSI: 5.07, StI: 55.1, FSI: 7.5

a. binder phase coke typical of this coal showing mainly fine- to medium-grained mosiac textures, fine pores; note the presence of inertinite (I)

b. binder coke showing abundant inertinite chars (I); pores are predominantly < 5 μm or > 30 μm

c. large pores in coke showing coherent wall structure

d. good bonding between vitrinite coke and inertinite (I)

e. coke area with relatively low pore density because of high inertinite (I) content

f to j are cokes from a blend of low volatile bituminous coals (mean VR_om: 1.55%), Lower Cretaceous Gates Formation, Smoky River Coalfield, northwestern Alberta; CBI: 4.02, CSI: 6.82, StI: 49.3, FSI:5

f. coke from vitrite showing medium flow (lenticular) and medium grained mosaic textures

g. coarse flow (ribbon) textures associated with the walls of large pores in vitrite; this is the main coke texture derived from coal of this rank

h. good bonding between inertinites (I) and medium grained textures

i. semifusinite containing large pores

j. pyrolytic carbon (Pc) coating the surface of pores and coarse grained mosaic coke from vitrite

k to n are cokes from a blend of two medium volatile bituminous coals (mean VR_om: 1.16%), Jurassic–Cretaceous Mist Mountain Formation, Elk Valley Coalfield, British Columbia; CBI: 1.76, CSI: 4.32, StI: 50.3, FSI:6.5

k. coke with fine grained mosaic texture and isotropic inertinites (I) showing low porosity and good bonding; scale as shown in **a**

l. pores >100 μm in coke with fine grained mosaic (Mc) coated with isotropic, vesicular coke (Ic)

m. coke with fine grained mosaic texture and heterogeneous coalescing pores; scale as shown in **a**

n. isotropic inertinites (I) in coke with fine grained mosaics

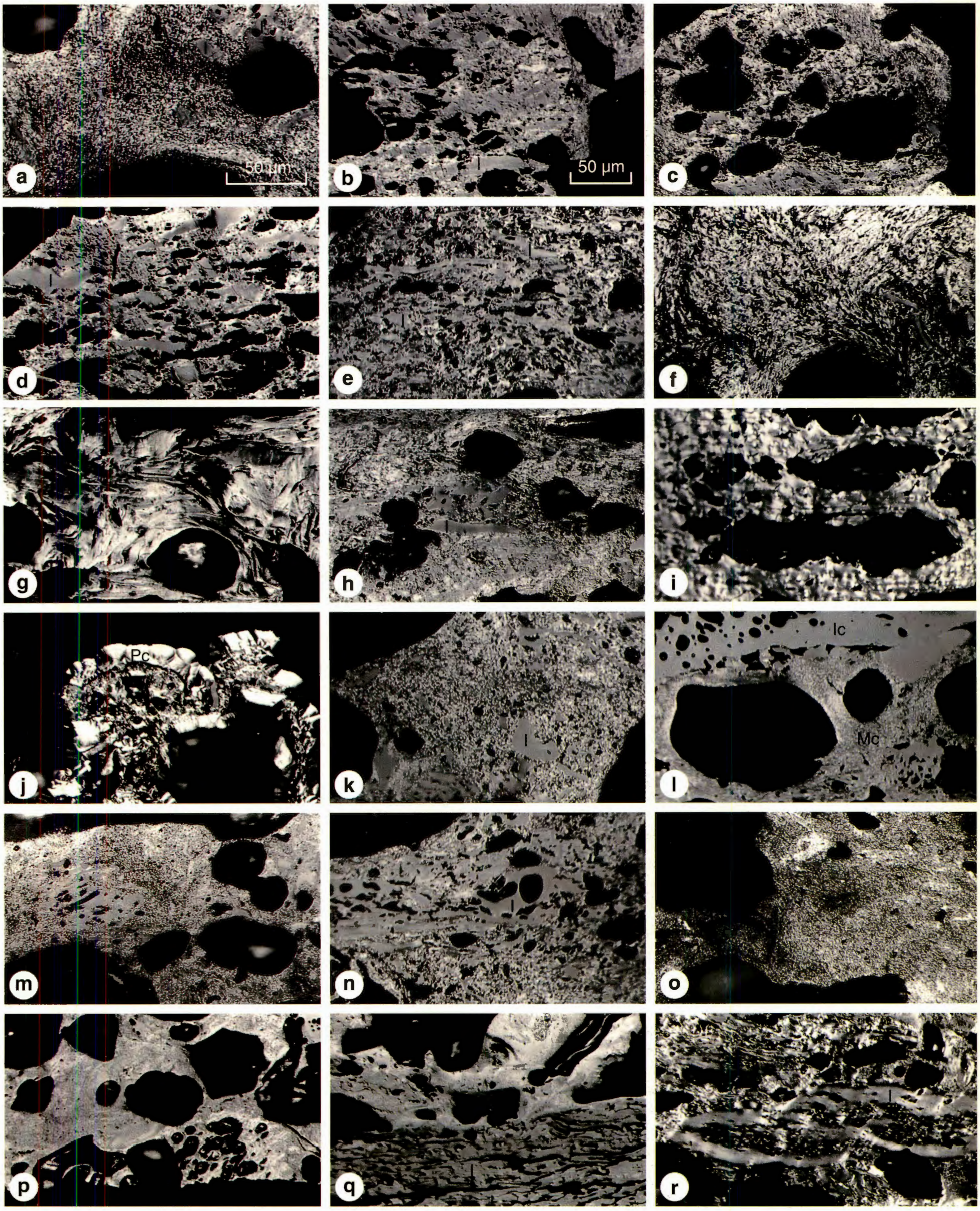
o to r are cokes from high volatile bituminous A coal (VR_om: 0.98%), Jurassic–Cretaceous Mist Mountain Formation, Elk Valley Coalfield, British Columbia; CBI: 0.50, CSI: 3.51, StI: 40.7

o. coke from vitrinite with very fine grained mosaic texture (main texture in this coke)

p. large irregular pores > 50 μm and small pores < 20 μm with narrow pore walls

q. large pores concentrated along boundaries between vitrinite coke and inertite (I) band

r. fine grained mosaic coke containing some slightly anisotropic inertinites (I)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REFERENCES: CARBONIZATION RESIDUES FROM CANADIAN COALS

Cameron A.R. and Botham, J.C. (1966). Petrography and carbonization characteristics of some western Canadian coals. In: Coal Science, R.F. Gould (ed.). Advances in Chemistry Series 55, American Chemical Society, Washington, D.C.: 564-576.

Furimsky, E., Palmer, A.D., Kalkreuth, W.D., Cameron, A.R. and Kovacik, G. (1990). Prediction of coal reactivity during combustion and gasification by using petrographic data. Fuel Processing Technology, V. 25: 135-151.

Grandsen, J.F., Jorgensen, J.G., Manery, N., Price, J.T. and Ramey, N.J. (1991). Applications of microscopy to coke-making. International Journal of Coal Geology, V. 19: 77-107.

Grint, A. and Marsh, H. (1981). Carbonization of coal blends: mesophase formation and coke properties. Fuel, V. 60: 1115-1120.

Hacquebard, P.A. (1960). The value of a quantitative separation of the maceral vitrinite into its constituents telinite and collinite for the petrography of coking coals. International Committee of Coal Petrology (ICCP) Proceedings, no. 3: 131-139.

Marchioni, D.L. (1983). The detection of weathering in coal by petrographic, rheological and chemical methods. International Journal of Coal Geology, V. 2: 231-259.

Nandi, B.N. and Montgomery, D.S. (1975). Nature and thermal behaviour of semifusinite in Cretaceous coal from Western Canada. Fuel, V. 54: 193-196.

Pearson, D.E. (1980). The quality of western Canadian coking coal. Canadian Institute of Mining and Metallurgy, Bulletin, V. 73: 1-15.

Pearson, D.E. (1991). Probability analysis of blended coking coals. International Journal of Coal Geology, V. 19: 109-119.

Pearson, D.E and Pearson, J.S. (1983). The reactivity of inertinites in coking coals from British Columbia (abstract). Canadian Institute of Mining and Metallurgy, Bulletin, V. 76: 52.

Schapiro, N. and Gray, R.J. (1964). The use of coal petrography in coke making. Journal of the Institute of Fuel, V. XI, No. 30: 234-242.

Thompson, R.R. and Benedict, L.G. (1975). Coal composition and its influence on coke-making. AIME Ironmaking Proc. V. 34: 112-132.

SECTION II DISPERSED ORGANIC MATTER AND BITUMENS

PLATE 16

DISPERSED ORGANIC MATTER
HERBACEOUS MACERALS: VITRINITE–INERTINITE–LIPTINITE

Photomicrographs **a** to **h**, **j** to **m** and **p** were taken using white incident light and oil immersion objectives, photos **i**, **n**, **o** and **q** to **v** were taken using fluorescent incident light and oil immersion objectives **magnification:** same for all photos; see scale bar in photo **v**

a. large **vitrinite** particle (V) in coaly shale; Carboniferous Stoddart Group, Alberta

b. **vitrinite** (V) in pyrite-rich marl; Triassic Schei Point Group, Canadian Arctic

c. **vitrinite** band (V) in shale; Triassic Schei Point Group, Canadian Arctic

d. **huminite** (H) in Upper Cretaceous Colorado Group shale, Williston Basin, Saskatchewan

e. low-reflecting **huminite** maceral (H) in crater facies of a kimberlite intrusion; probably Eocene age, Northwest Territories

f. **fusinite** (F) in shaly carbonate, Upper Carboniferous Golata Formation, Yukon Territory

g. **fusinite** (F) and inertodetrinite (I) in marlstone; Lower Carboniferous Emma Fiord Formation, Devon Island, Canadian Arctic

h,i. **fusinite** (F) and **inertodetrinite** (I) macerals within marlstone. Porosity associated with the fusinites is infilled with yellow-fluorescing **exsudatinite** (E). Photo **h** is white light image and photo **i**, fluorescent light; Lower Carboniferous Emma Fiord Formation, Devon Island, Canadian Arctic

j. **inertinite** derived from a terrestrial spore; Upper Devonian Dawson Bay Formation equivalent, Alberta Basin

k. **faunal inertinite** (arrow) within a bitumen-rich, carbonate and phosphate matrix; Upper Jurassic Nordegg Formation, Alberta

l. **inertinite** (I) derived from a filamentous alga or a fungal body (funginite?), viewed perpendicular to bedding; Upper Jurassic Nordegg Formation, Alberta

m. **inertinite** (I) derived from a filamentous alga or a fungal body (funginite?) viewed parallel to bedding; Upper Jurassic Nordegg Formation, Alberta

n. Middle Devonian **sporinite** viewed perpendicular to bedding; Elk Point Group, Alberta

o. Middle Devonian **sporinite** (S) in parallel-to-bedding view showing trilete mark; Elk Point Group, Alberta

p,q. Lower Carboniferous **sporinite** (S) shown perpendicular to bedding; **p** is white light image and **q**, fluorescent light. Note exine and endine layers in the sporinite; Lower Carboniferous Emma Fiord Formation, Devon Island, Canadian Arctic

r. Lower Carboniferous **sporinite** (S) shown parallel to bedding, showing trilete mark and associated with coccoidal *Pila* alginite (A); Emma Fiord Formation, Devon Island, Canadian Arctic

s. several varieties of **sporinite**, probably derived from spores; Lower Carboniferous Emma Fiord Formation, Devon Island, Canadian Arctic

t. echinate sculpture on a thick-walled **sporinite**; Lower Carboniferous Emma Fiord Formation, Devon Island, Canadian Arctic

u. gemmate sculpture on **sporinite**; Upper Carboniferous Mattson Formation, Yukon Territory

v. **sporinite** - sporangium viewed perpendicular to bedding; Upper Carboniferous Mattson Formation, Yukon Territory

PLATE 16

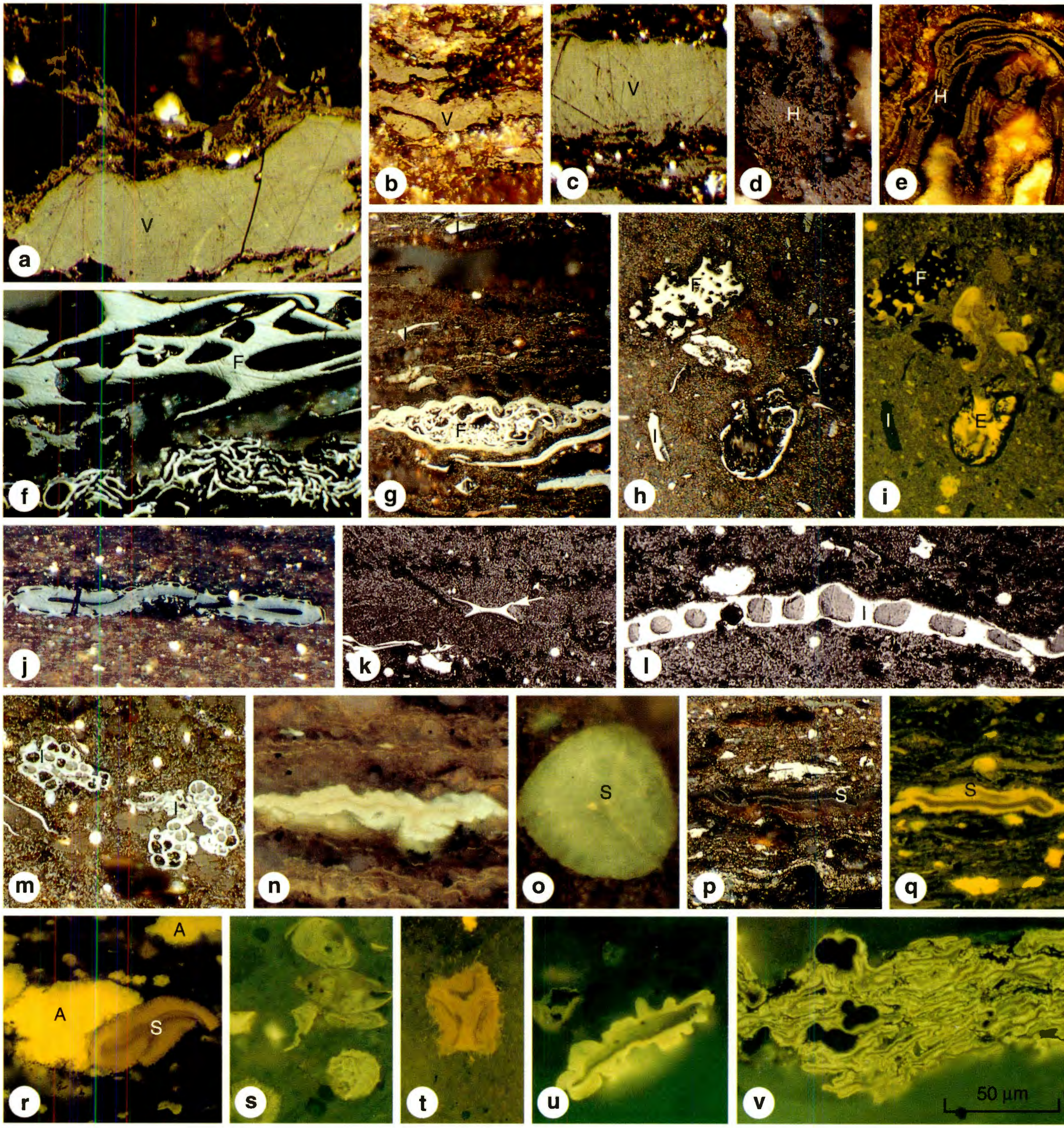

PLATE 17

DISPERSED ORGANIC MATTER
HERBACEOUS MACERALS: VITRINITE–INERTINITE–LIPTINITE

All photomicrographs were taken using fluorescent incident light, except photos **c** to **e**, **h** and **t** which were taken using white incident light
magnification: same for all photos; see scale bar in photo **v**

a. orange-fluorescing **sporinite** displaying zonation of the fluorescence intensity about the trilete mark; Upper Carboniferous, Mattson Formation, Yukon Territory

b. **sporinite** emitting variable fluorescence colours and a significant 'softening' or morphological distortion in response to thermal maturation and burial; Upper Devonian Duvernay Formation, Alberta Basin, Alberta; thermal maturity approximately 0.70%R_or (vitrinite equivalent)

c. **sporinite** from marginally mature, marine source rock, with minute inclusions of bitumen; Upper Devonian Duvernay Formation, Alberta Basin

d. **sporinite** from mature source rock showing micrinitized margin; Upper Devonian Duvernay Formation, Alberta Basin

e. **sporinite** from overmature source rock with inclusions of devolatilized bitumen (arrow); Upper Devonian Duvernay Formation, Alberta Basin

f,g. red-fluorescing **sporinite** viewed (**f**) perpendicular and (**g**) parallel to bedding; Upper Jurassic Vanguard Formation, Saskatchewan

h,i. Mesozoic **sporinite** showing trilete mark; **h** is white light image and **i**, fluorescent light; Upper Cretaceous Colorado Group, Saskatchewan

j,k. **sporinite** derived from pollen grains; Upper Cretaceous Colorado Group, Saskatchewan

l. **sporinite** derived from pollen found in crater facies of kimberlite intrusion; probably Eocene age, Northwest Territories

m. degraded **sporinite** derived from a pollen grain; Upper Triassic Schei Point Group, Canadian Arctic

n. thick-walled, orange-fluorescing **cutinite**; Lower Carboniferous Mattson Formation, Yukon Territory

o. thin-walled cuticular maceral (**cutinite?**); Upper Cretaceous Belly River Formation, Saskatchewan

p. thick-walled, yellow-fluorescing **cutinite** (Cu) from within crater facies of a kimberlite intrusion; probably Eocene age, Northwest Territories

q. **cutinite** (Cu) associated with **collodetrinite** (Cd) and fluorescing matrix bituminite; viewed perpendicular to bedding; Upper Devonian Beaverhill Lake Group, Alberta

r. citron-fluorescing **resinite** within vitrinite-rich (V) shale; Lower Cretaceous Mannville Group, Saskatchewan

s,t. sub-rounded particle of **resinite** with an alteration rim (probably due to oxidation) clearly visible in fluorescent light (**s**); Upper Cretaceous Colorado Group, Saskatchewan

u. yellow-fluorescing **resinite** (possibly fluorinite; arrows) within "**phyllovitrinite**" (V); Upper Devonian Beaverhill Lake Group, Alberta

v. red-fluorescing chlorophyllinite (arrow) within dark "phyllovitrinite" (V) embedded in a fluorescing matrix bituminite; Upper Devonian Beaverhill Lake Group, Alberta (note the red colour fades very rapidly during exposure to uv light)

PLATE 17

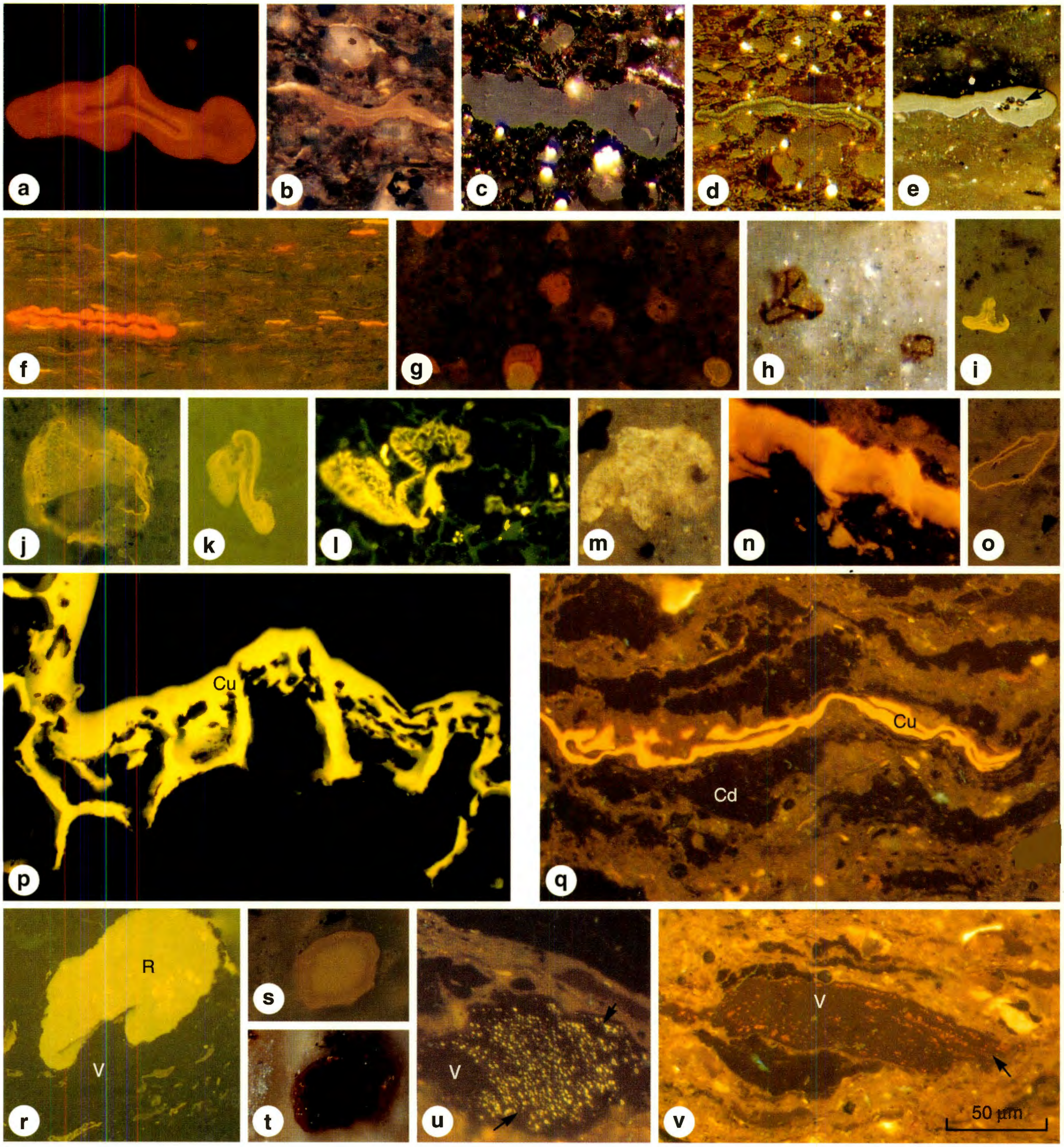

PLATE 18

DISPERSED ORGANIC MATTER
AMORPHOUS MACERALS: HEBAMORPHINITE AND FLUORAMORPHINITE

Photomicrographs **a** to **f** were taken using white incident light, photos **g** to **p** were taken using fluorescent incident light
magnification: scale in photo **p** applies to all except photo **h**

a. finely dispersed, grey, granular **hebamorphinite** (arrow) within pyrite-rich, marl matrix; commonly referred to as "**matrix bituminite**"; Upper Cretaceous Colorado Group, Saskatchewan

b. somewhat concentrated, granular **hebamorphinite** (arrows) within pyrite-rich, marl matrix, under partly crossed polars; Upper Cretaceous Colorado Group, Saskatchewan

c,d,e. continuous network of **hebamorphinite** (H) within pyrite and *Tasmanites* alginite (A)-rich shale matrix; viewed perpendicular to bedding; lenses of granular, grey material in **c** and **d** are micrinite derived from bacterial remains; Upper Devonian–Upper Mississippian Bakken Formation, Williston Basin, Saskatchewan

f,g. sieve-like network of **fluoramorphinite**-matrix bituminite (F); also present is phosphatic nodule (P) with inclusions of migra-bitumen (B); **f** is shown in white light and **g** in fluorescent light; Upper Devonian Exshaw Formation, Alberta

h. non-fluorescing **hebamorphinite** (H) layer interbedded with diffuse **fluoramorphinite** (F), viewed perpendicular to bedding; unicellular **alginite** (A) also present; Middle Devonian Keg River Formation, Alberta

i. degraded and diffuse **fluoramorphinite** (F) within intercrystalline regions of bioturbated, carbonate matrix; viewed parallel to bedding; Middle Devonian Keg River Formation, Alberta

j. non-fluorescing **hebamorphinite** (H) within a very fine grained, carbonate matrix in perpendicular-to-bedding view; unicellular alginite (A) also present; Middle Devonian Keg River Formation, Alberta

k. reddish brown to red-fluorescing, diffuse to concentrated **fluoramorphinite** (F) associated with red-fluorescing, unicellular **alginite** (A); Upper Devonian Duvernay Formation, Alberta

l. concentrated **fluoramorphinite** (lamalginite) within fine grained, platformal **algal mat**, carbonate source rock; Middle Devonian Winnipegosis Formation, Williston Basin, Saskatchewan

m. highly concentrated **fluoramorphinite** (F) with numerous inclusions of yellow-fluorescing, unicellular **alginite** (A) in a fine grained, platformal, stromatolitic carbonate source rock; Upper Ordovician Yeoman Formation, Saskatchewan

n. filamentous **alginite** (A) showing cellular structure (arrows) associated with yellow-fluorescing **fluoramorphinite** (F) alternating with weak brown- to non-fluorescing **hebamorphinite** (H) within anhydritic, fine grained, carbonate source rock; Middle Devonian Keg River Formation, Alberta

o,p. concentrated **fluoramorphinite** (F) transitional to low-reflecting ($<0.15\%R_or$) primary **bitumen** (B), within a stromatolitic, platformal, carbonate source rock containing filamentous **alginite** (A); **o** is shown perpendicular to bedding and **p** is shown parallel to bedding through a stromatolitic pustule; Middle Devonian Winnipegosis Formation, Manitoba

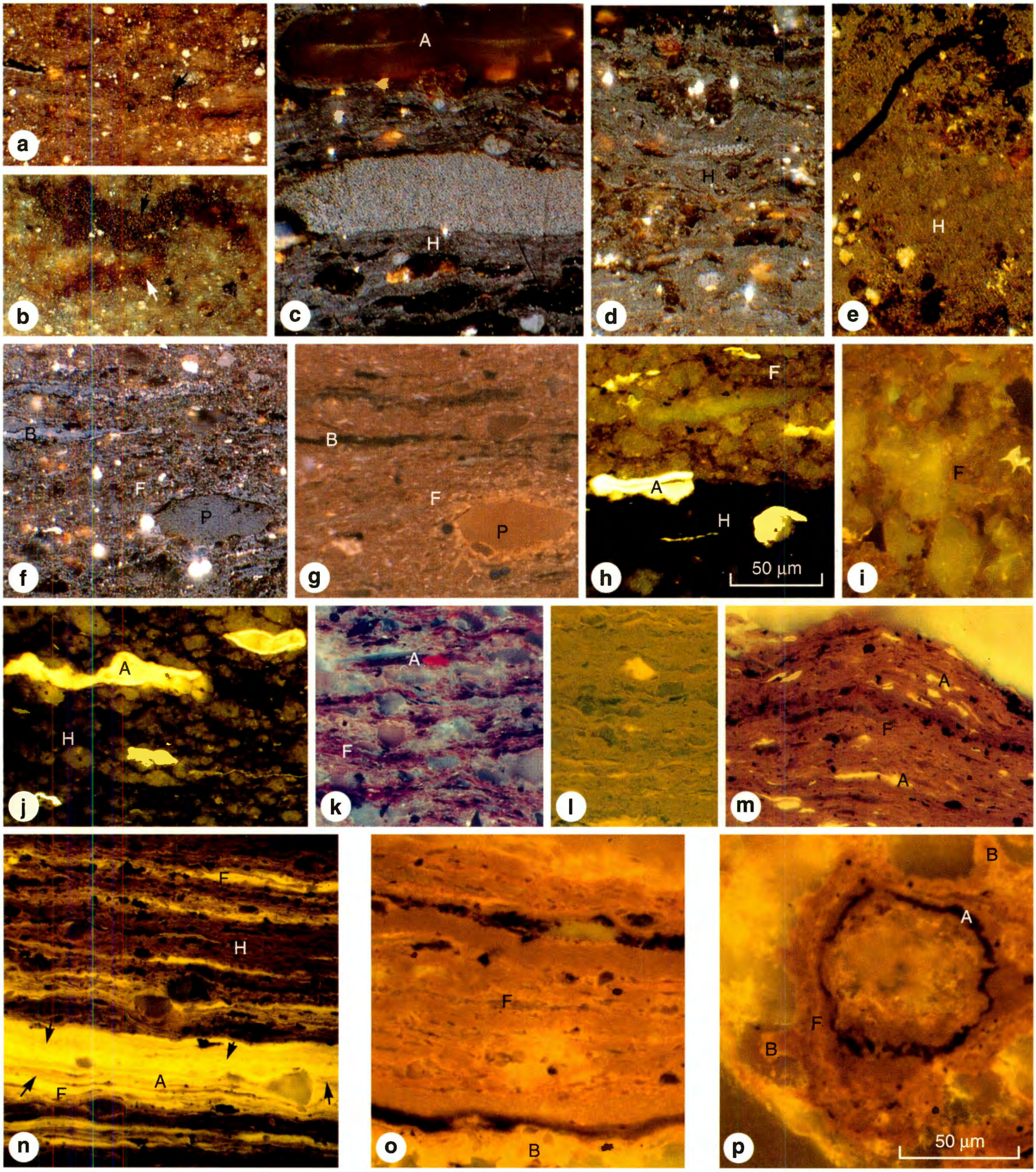
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PLATE 19

DISPERSED ORGANIC MATTER
ALGINITE: COCCOIDAL AND UNICELLULAR

All photomicrographs were taken using fluorescent incident light,
except photo **e** which was taken using white incident light
magnification: same for all photos; see scale bar in photo **s**

CAMBRO–ORDOVICIAN

a,b,c. coccoidal **alginite** (A) probably derived from *Gloeocapsomorpha prisca* or *G. heibeica*; **a** and **b** are shown perpendicular to bedding, **c** is parallel to bedding; Upper Cambrian Deadwood Formation, Saskatchewan

d. coccoidal **alginite** showing "budding" of coccoidal cells; Upper Cambrian Deadwood Formation, Saskatchewan

e. highly mature coccoidal **alginite** (A) (dry gas generation zone); Middle Cambrian Pika Formation, Alberta

f,g. unicellular *Symplassisphaeridium*-like (**f**) and *Leiosphaeridia*-like (**g**) **alginites**, Upper Cambrian Deadwood Formation, Saskatchewan

h. *Tasmanites*-like **alginite** (A), Upper Cambrian Earlie Formation, Saskatchewan

i. small agglomerations of coccoidal *G. prisca* **alginite** (G) parallel to bedding view; Middle–Upper Ordovician Winnipeg Formation, Saskatchewan

j,k. coccoidal *G. prisca* **alginite** (G) viewed perpendicular to bedding; cell structure is mainly obscure in **k**; coccoidal cellular structure is more clearly defined in **j**; Upper Ordovician Yeoman Formation, Williston Basin, Saskatchewan

l. tightly packed, small agglomerations of *G. prisca* **alginite** (G) with obscure coccoidal cell structure; Upper Ordovician Yeoman Formation, Williston Basin, Saskatchewan

m,n. colonies of *G. prisca* **alginite** (G) with subtle coccoidal cell structure; Upper Ordovician Yeoman Formation, Williston Basin, Saskatchewan

o. coccoidal *G. prisca* **alginite** (G) with algal mat-texture; Middle Devonian Ashern Formation, Alberta Basin; Alberta

DEVONIAN–CARBONIFEROUS

p. coccoidal *Botryococcus*-like **alginite** (A) (also referred to as *Pila* in Paleozoic rocks) associated with microsporinite (S); Middle Devonian Winnipegosis Formation, Alberta

q,r,s. coccoidal *Pila-Botryococcus* **alginite** (A) with barely recognizable remnant cell structure visible in **q** and **s**; the subtle cell structure in **r** has been enhanced by prolonged exposure to ultraviolet light; viewed perpendicular to bedding; Carboniferous Emma Fiord Formation, Grinnel Peninsula, Devon Island, Canadian Arctic

PLATE 19

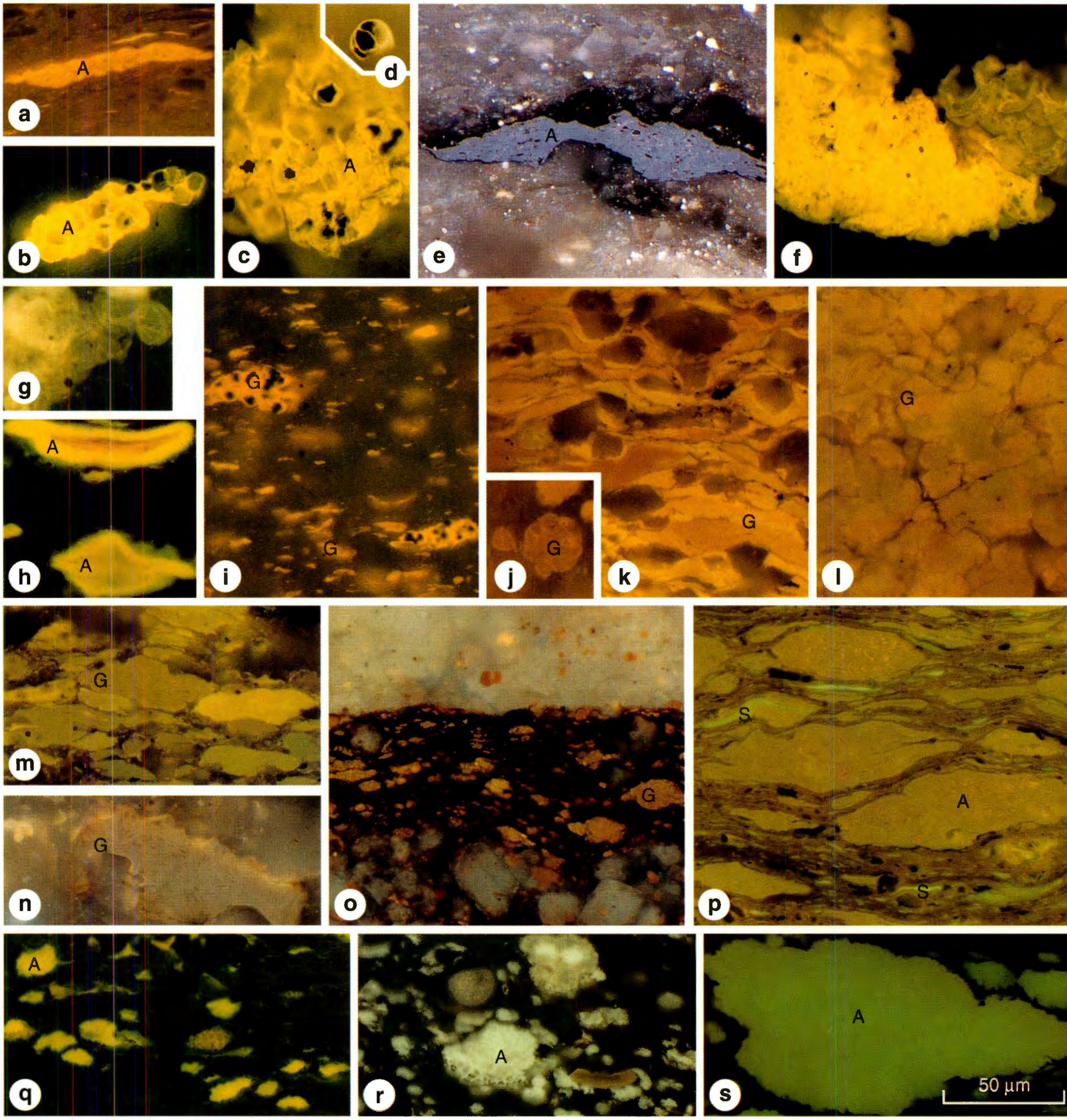

PLATE 20

DISPERSED ORGANIC MATTER
ALGINITE: UNICELLULAR, FILAMENTOUS AND COCCOIDAL

All photomicrographs were taken using fluorescent incident light and oil immersion objectives, except photos **f**, **j** and **l** which were taken using white incident light
magnification: scale in photo **k** applies to all except photo **a**

DEVONIAN–CRETACEOUS

a. concentration of unicellular, Prasinophyte **alginites** (arrows) associated with carbonate microfossils (cricoconarid) and weak-fluorescing amorphinite (A); viewed perpendicular to bedding; Middle Devonian Winnipegosis Formation, Saskatchewan

b. relatively thin-walled *Leiosphaeridia* **alginite** viewed perpendicular to bedding; Upper Devonian–Mississippian Bakken Formation, Williston Basin, Saskatchewan

c. thick-walled unicellular *Tasmanites* **alginite** viewed perpendicular to bedding; the margins of this alginite commonly display punctation; Middle Devonian Kettle Point Formation, Michigan Basin, southern Ontario

d. thin-walled *Leiosphaeridia* **alginite** (A), shown parallel to bedding; Upper Devonian Wabamun Formation, Alberta

e. thick-walled unicellular *Tasmanites* **alginite** (A) viewed parallel to bedding; the margins of this alginite display punctation; southwestern Ontario

f. *Tasmanites* **alginite** (A) showing clear punctation and pore canals, viewed in white light; Upper Cretaceous Second White Speckled Shale, Saskatchewan

g. thin-walled *Leiosphaeridia* **alginite** (A) showing an 'artificial trilete mark' viewed parallel to bedding; Upper Devonian–Mississippian Bakken Formation, Williston Basin, Saskatchewan

h. massive filamentous **alginite** (A) cell structure in stromatolitic habit, viewed perpendicular to bedding; Lower Devonian Disappointment Bay Formation, Truro Island, Canadian Arctic

i. fluorescing, filamentous **alginite** (A) with quadrate cellular structure in stromatolitic habit; Middle Devonian Prairie Formation, Alberta

j. *Nostoc*-like, non-fluorescing, filamentous **alginite** (A) viewed in white light; Middle Devonian Winnipegosis Formation, Saskatchewan

k. *Botryococcus* **alginite** (A) clearly illustrating cup structure of the precursory colonial algae; Mesozoic Sverdrup Basin, Canadian Arctic

l,m. *Botryococcus* **alginite** (A) with serrated margins viewed parallel to bedding, in white (**l**) and fluorescent light (**j**); Lower Tertiary, Indonesia

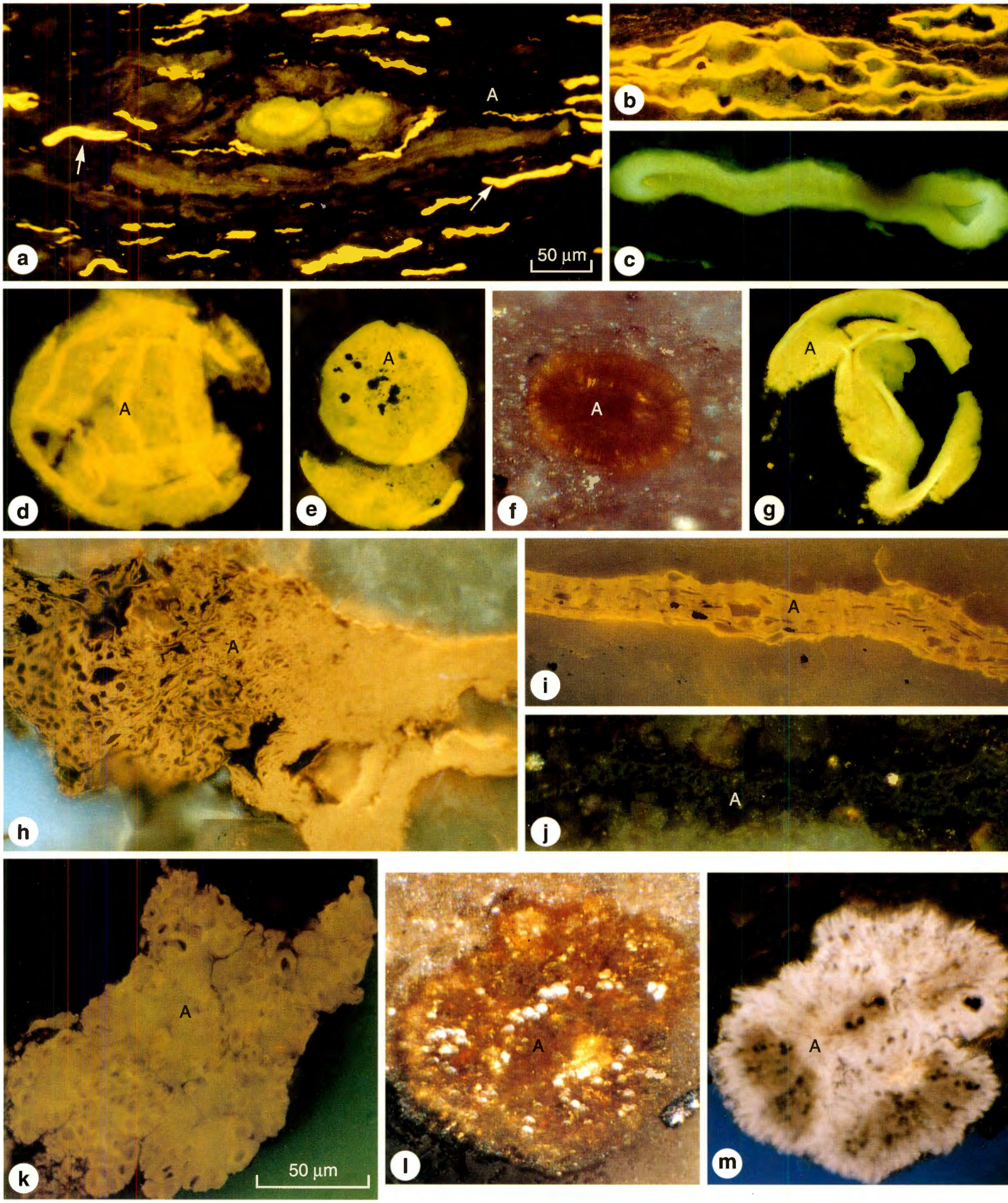
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PLATE 21

DISPERSED ORGANIC MATTER
MISCELLANEOUS ALGINITES, ACRITARCHS AND ALGAL MAT MICROTEXTURES

All photomicrographs were taken using fluorescent incident light
magnification: scale in photo **q** applies to all except photos **t**, **u** and **v**; scale for these is in photo **t**

Acritarchs

m. acanthomorphic **acritarch** with morphology similar to *Orthosphaeridium* cf.; Middle Devonian Marcellus Formation, southwestern Ontario

c. spiny, acanthomorphic **acritarch** (A) associated with *Tasmanites* alginite (T); Middle Silurian Aromosa Member of Guelph Formation, southwestern Ontario

d,e. *Multiplicisphaeridium* cf. acanthomorphic **acritarchs**; Upper Devonian Duvernay Formation, Alberta

f,h,i. *Micrhystridium* cf. acanthomorphic **acritarchs**, Upper Devonian Duvernay Formation, Alberta

g,l. *Veryachium* cf. **acritarch**; **g** is from Middle Devonian Marcellus Formation, southwestern Ontario; **l** is from Upper Devonian Duvernay Formation, Alberta

j,k. *Hystricosphaeridium* cf. **acritarch**; Upper Devonian Duvernay Formation, Alberta

m,n. spiny, (?) acanthomorphic, marine **acritarchs**; Middle Devonian Pine Point Formation, Northwest Territories

o. **dinoflagellate**; Upper Jurassic Kimmeridge shale, North Sea

p,q,r,s. **dinoflagellates** illustrating 'artifacts' produced by grinding and polishing of whole rock sample, Upper Cretaceous Colorado Group, Saskatchewan

Algal mat–stromatolitic microtextures

t. algal head or pustule produced by growth of *Gloeocapsomorpha prisca* **alginite**, Upper Ordovician Yeoman Formation, Saskatchewan

u alternating horizontal and vertical algal growth perhaps representing day time–night time gliding; *Gloeocapsomorpha prisca* **alginite**; Upper Ordovician Yeoman Formation, Saskatchewan

v. domal stromatolitic microtextures developed by growth of filamentous **alginite** and *Gloeocapsomorpha prisca* **alginite**; also note associated hardground and carbonate particles trapped in mat; Upper Ordovician Yeoman Formation, Saskatchewan

w. planar, laminated, algal mat produced by *Gloeocapsomorpha prisca* **alginite**; note fluorescing halo in the alginite surrounding a radioactive, detrital mineral (M) which shows a significant "blue-shift" in the fluourescence properties; Upper Ordovician Yeoman Formation, Saskatchewan

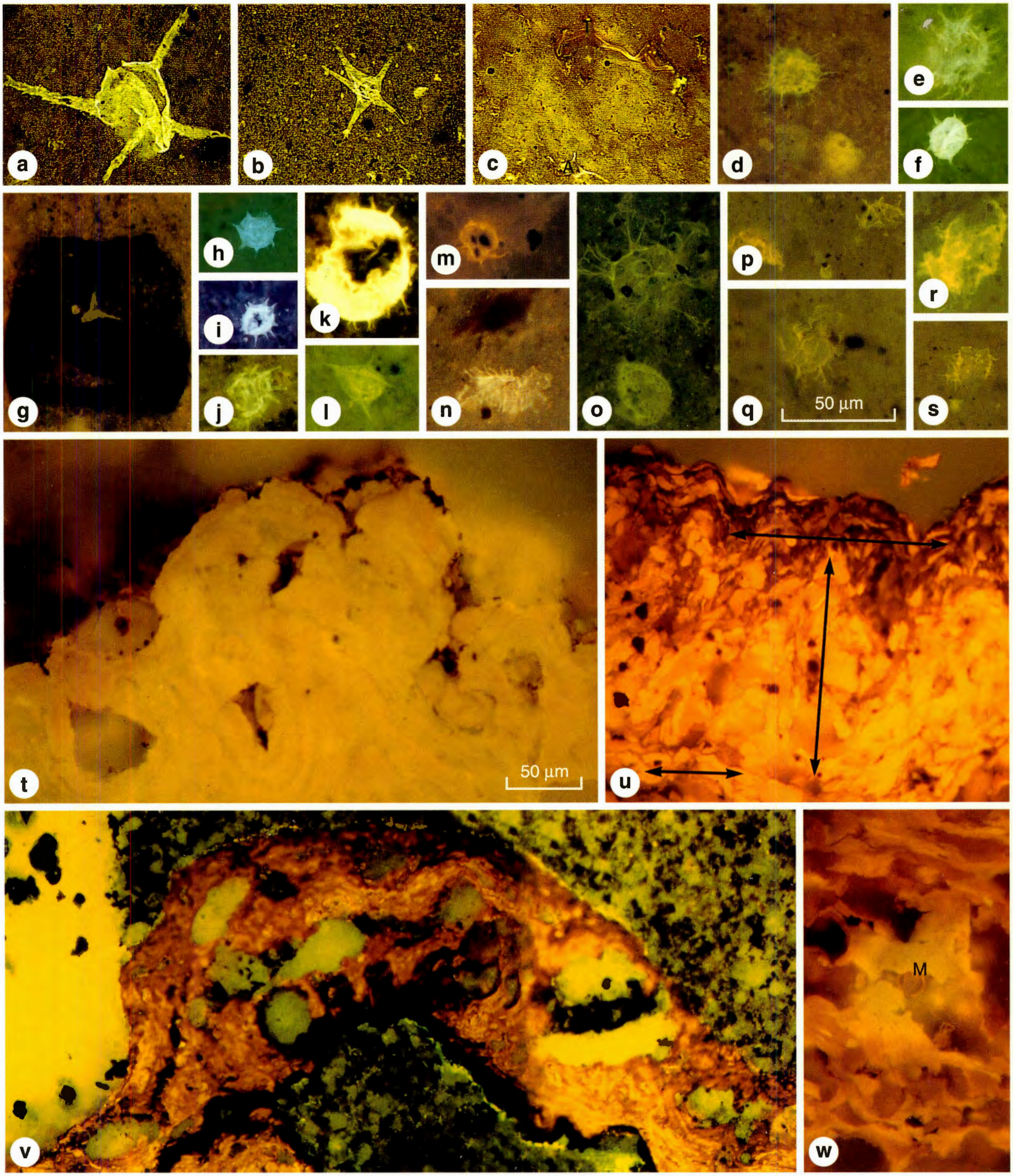
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PLATE 22

DISPERSED ORGANIC MATTER
ALGAL MAT MICROTEXTURES

All photomicrographs were taken using fluorescent incident light, except photo **c** which was taken using white incident light
magnification: scale in photo **i** applies to all except photos **a**, **b**, **f** and **e**; scale for these is in photo **a**

a. pinnacle stromatolite microtextures formed by growth of filamentous **alginite** and *Gloeocapsomorpha prisca* **alginite**; also note associated hardground and carbonate particles trapped in mat; Upper Ordovician Yeoman Formation, Saskatchewan

b. brecciated algal mats consisting of **fluoramorphinite** (F) and filamentous **alginite** (A); crinkle-style lamination (K) and unicellular **sphaeromorphs** (S) are evident in the mats; Upper Ordovician Yeoman Formation, Saskatchewan

c,d. algal mat-derived **fluoramorphinite** (F) within platformal, immature, carbonate hydrocarbon source rocks; note the thin lamina of high-reflecting, non-fluorescing filamentous **alginite** (A) with well-preserved cell structure; viewed perpendicular to bedding; **c** is plane polarized white light image; **d** is fluorescent light image; Middle Devonian Winnipegosis Formation, Manitoba

e. **fluoramorphinite** (F) formed from algal-bacterial (?) mats within platformal, anhydritic carbonate source rocks; Middle Devonian Dawson Bay Formation, Saskatchewan

f. **fluoramorphinite** (F) formed from algal-bacterial (?) mats associated with stromatoporoids in anhydritic carbonate source rock; upper Middle Devonian Beaverhill Lake Group, Alberta

g. algal mat-derived **fluoramorphinite** (F) within platformal, immature carbonate source rocks; note the thin lamina of non-fluorescing filamentous **alginite** (A); compare with (**c**) and (**d**); bitumen (B) is also present; viewed parallel to bedding; Middle Devonian Winnipegosis Formation, Manitoba

h. filamentous **alginite** (A) with cell structure (arrow) preserved within algal mat-derived **fluoramorphinite** (F); carbonate source rock in Lower Devonian Disappointment Bay Formation, Truro Island, Canadian Arctic

i. filamentous **alginite** (A) cell structure (arrow) well-preserved and "exploded" by growth of primary anhydrite in dolomitic anhydrite, lagoonal source rock; Middle Devonian Prairie Formation, Alberta

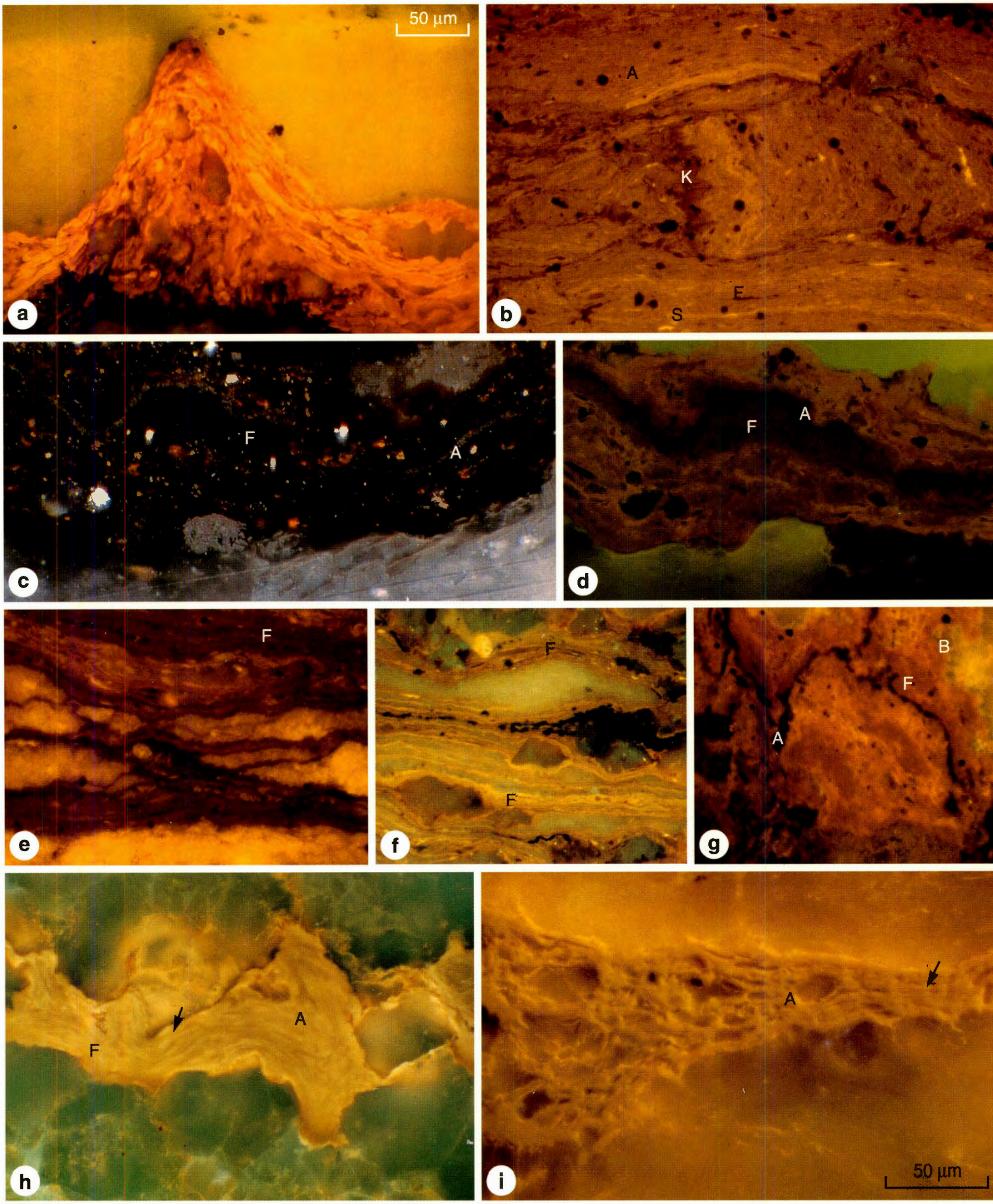
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PLATE 23

DISPERSED ORGANIC MATTER
ORGANIC FOSSILS

All photomicrographs were taken using incident white light,
except photos **l** to **p** and **s** which were taken using incident fluorescent light
magnification: same for all photos; see scale bar in photo **p**

a. **graptolite**; Ordovician to Silurian Cape Phillips Formation, Baillie Hamilton Island, Canadian Arctic

b. Ordovician **graptolite** showing the fusellar structure of the periderm; Ordovician Upper Thumb Mountain Formation, Little Cornwallis Island, Canadian Arctic

c. **graptolite** showing the fusellar structure of the periderm; Lower Ordovician to Lower Devonian Road River Group, Yukon Territory

d,e. open, spiny **chitinozoan** (**d**) and flattened **chitinozoan** (**e**) viewed perpendicular to bedding; Upper Ordovician Collingwood member, Whitby Formation, southwestern Ontario

f. **chitinozoan**; Devonian Upper Gaspé Limestone, Indian Cove Formation, Appalachians, Gaspé, Quebec

g. Upper Ordovician **chitinozoan** viewed parallel to bedding; Ordovician Collingwood member, Whitby Formation, Ontario

h. **scolecodont** illustrating the dentary; Silurian Anticosti Group, Gun River Formation, Anticosti Island, Quebec

i. **scolecodont** illustrating porate, surficial texture; Ramparts Formation, Northwest Territories

j. **scolecodont**; Upper Devonian Wabamun Formation, Home Beaver Lodge, Alberta

k. **foraminifera** with chitinous chamber lining preserved; Jurassic, Switzerland

l,m,n. fungal remains **(funginite)** showing sac-like (arrow) (**l**), filamentous (**m**) and, tubular and spherical morphology (**n**); **l** and **n** from Lower Devonian Disappointment Bay Formation, Truro Island, Canadian Arctic; **m** from the Middle Devonian Winnipegosis Formation, Alberta

o. **fish bone** viewed under fluorescent light; Second White Specks, Colorado Group, Saskatchewan

p. **chitinous** portion of conchostracan fossil (shrimp-like) showing porate surface texture; Middle Devonian (Dawson Bay Formation equivalent), Alberta

q. **bone** (chitinous ?) with fine pores visible in left portion of photo; Upper Devonian–Mississippian Bakken Formation, Saskatchewan

r, s. **fish remains** (chitinous?) viewed under plane polarized white (**r**) and fluorescent light (**s**); photo rotated through 180°; Upper Cretaceous Second White Speckled shale, Colorado Group, Saskatchewan

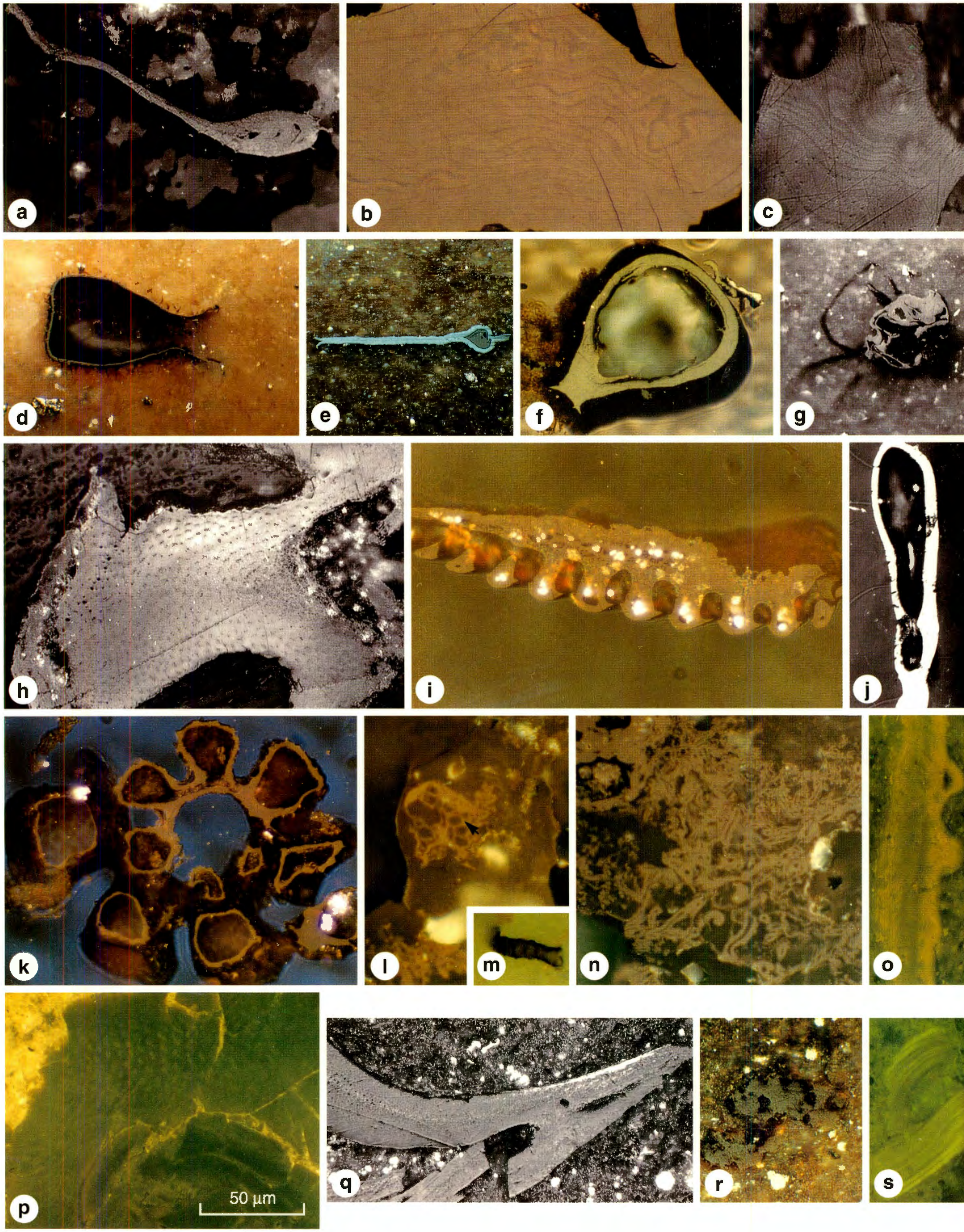
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PLATE 24

DISPERSED ORGANIC MATTER
BITUMENS

Photomicrographs **a** to **d**, **i**, **k** and **l** were taken using fluorescent incident light,
photos **e** to **h**, **j** and **m** to **p** were taken using white incident light
magnification: same for all photos; see scale bar in photo **l**

s. fluorescing **primary bitumen** (B) and **oily bitumen** within primary pores and microfractures of platformal carbonate source rock; the bitumen was generated directly from associated thermally immature (0.50%R_or, vitrinite equivalent), sulphur-rich fluoramorphinite (F) and filamentous alginite (A) stromatolites; viewed perpendicular to bedding plane; Middle Devonian Winnipegosis Formation, Manitoba

c,d. fluorescing, **primary bitumen** (B) **(exsudatinite)** infilling cell lumens and primary cell structure of inertinites in thermally immature oil shale (0.40%R_or, vitrinite equivalent); Lower Carboniferous Emma Fiord Formation, Devon Island, Canadian Arctic

e. dark grey-reflecting, non-fluorescing **primary bitumen** (B) infilling the interior and microfractures within phosphatic particle; Lower Jurassic Nordegg Formation, Alberta

f. non-fluorescing, **primary bitumen** (B) in 'bedding plane separation' habit associated with diffuse to concentrated amorphinite (A) in fine grained carbonate basinal source rock; Upper Devonian Duvernay Formation, Alberta

g. grey-reflecting, non-fluorescing **primary bitumen** (B) associated with coccoliths; Lower Jurassic Nordegg Formation, Alberta Basin, Alberta

h. low-reflecting, granular, non-fluorescing **primary bitumen** (B) (0.12%R_or) within intercrystalline porosity of carbonate kukersite source rock; Upper Ordovician Yeoman Formation, Williston Basin, Saskatchewan

i. low intensity, brown, fluorescing, oily **migrabitumen** (B) within microfracture; **oil globules** (O) exude from the microfracture during prolonged exposure to ultraviolet light; Upper Devonian Duvernay Formation, Alberta

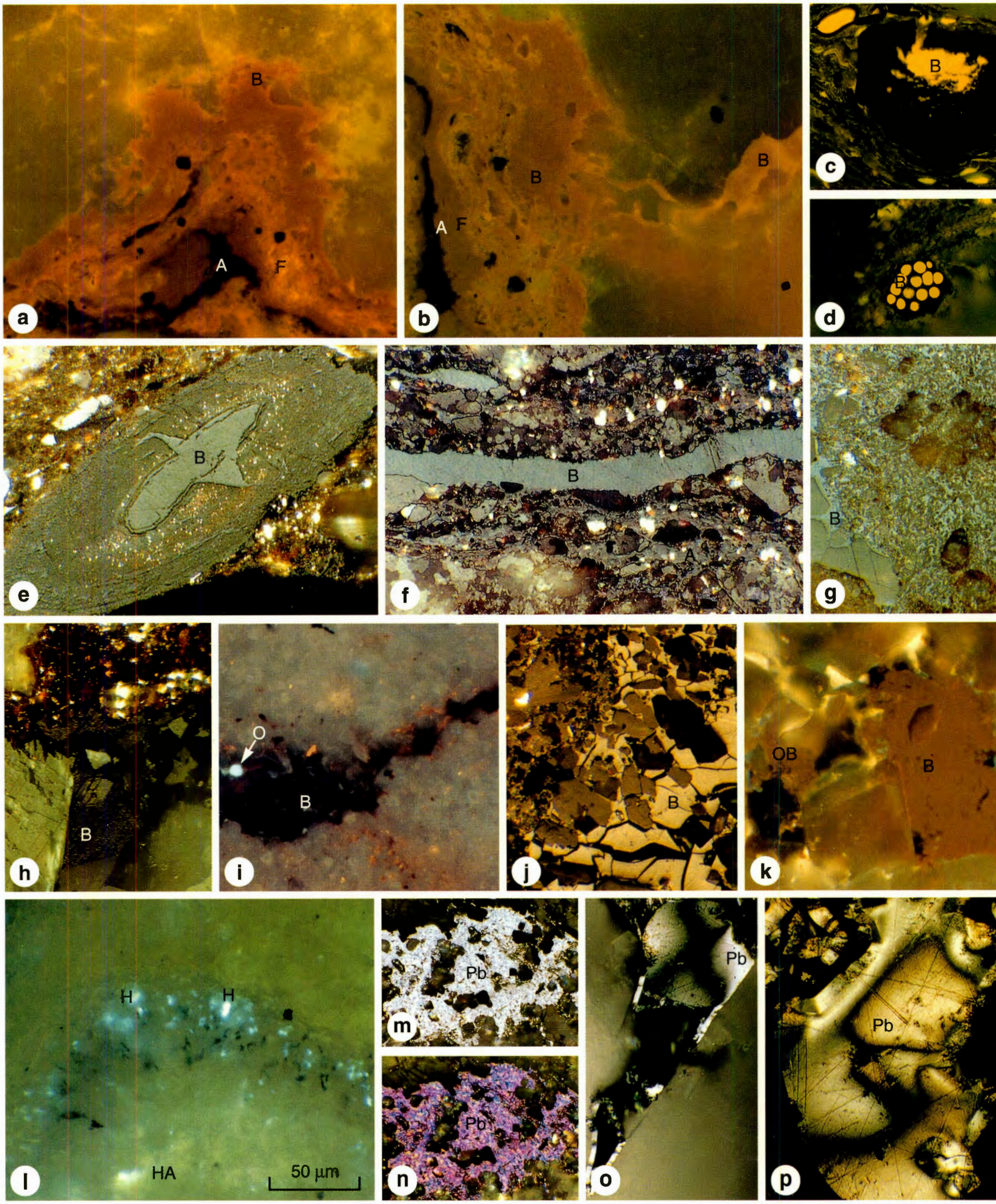
j. isotropic **bitumen** (B) with inclusions of calcite from thermally overmature (1.4%R_or vitrinite equivalent), carbonate source rock; Upper Devonian Duvernay Formation, Alberta

k. fluorescing **migrabitumen** (B) (0.12%R_or), **oily bitumen** (OB) and hydrocarbon fluid inclusions within recrystallized and hydrothermally altered carbonate source rock interval; Lower Devonian Disappointment Bay Formation, Truro Island, Canadian Arctic

l. blue-fluorescing, **hydrocarbon fluid inclusions** (H) trapped at the margins and yellow-fluorescing, **hydrocarbon fluid inclusion** (HA) in the core of a rounded, carbonate allochem; Upper Devonian Birdbear Formation, Saskatchewan

m,n. anisotropic **pyrobitumen** (Pb) showing fine grained, mosaic texture (3.30%VR_om; 1.98%$R_o$min) within reefal gas reservoir; **m** is viewed in plane polarized light; and **n** is viewed under cross-polars with a lambda plate insert; this type of pyrobitumen was derived from a non-graphitizing source (e.g. asphaltic bitumen); Upper Devonian Leduc Formation, Alberta

o,p. anisotropic **pyrobitumen** (pyrobitumen) (Pb) (6.5%R_om; 0.55%$R_o$min), shown under cross-polars, from a reefal carbonate gas reservoir; **o** shows a mesophase sphere in the **pyrobitumen** with a "Brewsters cross"; the **pyrobitumen** (Pb) in **p** displays a coarse-flow mosaic to domain coke texture; this type of pyrobitumen was derived by thermal cracking of crude oil to gas; Upper Devonian Leduc Formation, Alberta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REFERENCES: DISPERSED ORGANIC MATTER IN CANADIAN PETROLEUM SOURCE ROCKS

Bertrand, R. (1991). Maturation thermique des roches mères dans les bassins des basses-terres du St. Laurent et des quelques buttes temoins au sud-est du Bouclier-canadien. International Journal of Coal Geology, V. 19: 359-384.

Bertrand, R. and Héroux, Y. (1987). Chitinozoan, graptolite and scolecodont reflectance as an alternative to vitrinite and pyrobitumen reflectance in Ordovician and Silurian strata, Anticosti Island, Quebec, Canada. American Association of Petroleum Geologists, Bulletin, V. 71, 8: 951-957.

Bustin, R.M. (1997). Petroleum source rocks, organic maturation and thermal history of the Queen Charlotte Basin, British Columbia. Bulletin of Canadian Petroleum Geology, V. 45: 255-278.

Bustin, R.M. (1995). Petroleum source rocks and organic maturation in Tofino Basin. Bulletin of Canadian Petroleum Geology, V. 43: 177-186.

Bustin, R.M.(1984). Coalification levels and their significance in the Groundhog coalfield, north-central British Columbia. International Journal of Coal Geology, V. 4: 21-44.

Bustin, R.M. and Mastalerz, M. (1994). Organic petrology and geochemistry of source rocks of the Later Triassic and Early Jurassic Sandilands and Ghost Creek Formations, Queen Charlotte Islands. Marine and Petroleum Geology, V. 12: 70-81.

Bustin, M.R., Vellutini, D. and Goodarzi, F. (1990). Petroleum source-rock characteristics of the Tertiary Skonun Formation, Queen Charlotte Islands, Hecate Strait and Queen Charlotte Sound, British Columbia. In: Current Research, Part F, Geological Survey of Canada, Paper 90-1F: 87-94.

Bustin, R.M. and McCauley, G. (1988). Organic petrography and Rock-Eval pyrolysis of the Ghost Creek and Sandilands Formations; Queen Charlotte Islands. Bulletin of Canadian Petroleum Geology, V. 36: 168-176.

Caplan, M. and Bustin, R.M. (1996). Factors governing organic matter preservation potential in marine petroleum source rocks from paleocontinental margins: Evidence from Upper Devonian to Lower Carboniferous Exshaw Formation. Bulletin of Canadian Petroleum Geology, V. 44: 474-494.

Chow, N., Wendte, J. and Stasiuk, L.D. (1995). Productivity versus preservation controls on two organic-rich carbonate facies in the Devonian of Alberta: sedimentological and organic petrological evidence. Bulletin of Canadian Petroleum Geology, V. 43: 433-460.

Clegg, H., Horsefield, B., Stasiuk, L., Fowler, M. and Vliex, M. (1997). Geochemical characterisation of facies variations in the Keg River Formation (Elk Point Group, Middle Devonian), La Crete Basin, western Canada. Organic Geochemistry, V. 26: 627-644.

Creaney, S., Allan, J., Cole, K., Brooks, P., Fowler, M., Osadetz, K., Snowdon, L., Macqueen, R.W. and Riediger, C.L. (1994). Hydrocarbon generation and migration in the Western Canada Sedimentary Basin. In: Geological Atlas of the Western Canada Sedimentary Basin, G.D. Mossop and I. Shetson (comps.). Canadian Society of Petroleum Geologists and Alberta Research Council, p. 455-468.

Disnard, J. et Héroux, Y., 1995. Biodégradation et lessivage des hydrocarbures au sein d'une série sédimentaire. Les Formations paléozoïques de l'environnement du gisement Zn-Pb de Polaris (TNO, Canada) Canada. Canadian Journal of Earth Sciences, V. 32: 1017-1034.

Dixon, J. and Stasiuk, L.D. (in press). Stratigraphy and hydrocarbon potential of Cambrian strata, northern interior plains, Northwest Territories. Bulletin of Canadian Petroleum Geology.

England, T.D.J. and Bustin, R.M. (1986). Thermal Maturation of the Western Canadian Sedimentary Basin south of the Red Deer River I: Alberta Plains. Bulletin of Canadian Petroleum Geology, V. 34: 71-90.

Feinstein, S., Goodarzi, F., Gentzis, T., Snowdon, L.R. and Williams, G.K. (1989). Preliminary organic maturation studies of Horn River strata in the Tathlina High area, Northwest Territories. In: Current Research, Part G, Geological Survey of Canada, Paper 89-1G: 43-50.

Feinstein, S., Williams, G.K., Snowdon, L.R., Goodarzi, F. and Gentzis, T. (1991). Thermal maturation of organic matter in the Middle Devonian to Tertiary section, Fort Norman area (Central Mackenzie Plain). Canadian Journal of Earth Sciences, V. 28, 7: 1009-1018.

Feinstein, S., Williams, G.K., Snowdon, L.R., Brooks, P.W., Fowler, M.G., Goodarzi, F. and Gentzis, T. (1991). Organic geochemical characterization and hydrocarbon generation potential of Mid-Late Devonian Horn River bituminous shales, Southern Northwest Territories, Canada. Bulletin of Canadian Petroleum Geology, V. 39, 2: 192-202.

Fowler, M.G. (1992). The influence of *Gloeocapsomorpha prisca* on the organic geochemistry of oils and organic-rich rocks of Late Ordovician age from Canada. In: Early Organic Evolution: Implications for Mineral and Energy Resources, M. Schidlowski et al. (ed). Springer-Velag, Berlin, p. 336-356.

Fowler, M.G., Kirste, D.M., Goodarzi, F. and Macqueen, R.W. (1993). Optical and geochemical classification of Pine Point bitumens and evidence for their origin from two different source rocks. Energy Sources, V. 15: 315-337.

Fowler, M.G., Hamblin, A.P., Hawkins, D., Stasiuk, L.D. and Knight, I. (1995). Petroleum geochemistry and hydrocarbon potential of Cambrian and Ordovician rocks of western Newfoundland. Bulletin of Canadian Petroleum Geology, V. 43: 187-213.

Fowler, M.G., Goodarzi, F., Gentzis, T. and Brooks, P.W. (1991). Hydrocarbon potential of Middle and Upper Devonian coals from Melville Island, Canadian Arctic. Organic Geochemistry, V. 17: 681-694.

Gentzis, T. and Goodarzi, F. (1993). Maturity studies and source-rock potential in the southern Sverdrup Basin, Canadian Arctic. International Journal of Coal Geology, V. 24: 141-177.

Gentzis, T., de Freitas, T., Goodarzi, F., Melchin, M. and Lenz, A. (1996). Thermal maturity of Lower Paleozoic sedimentary successions in Canadian Arctic. American Association of Petroleum Geologists, Bulletin, V. 80, 7: 1065-1084.

Gentzis, T. and Goodarzi, F. (1993). Regional thermal maturity and source-rock potential of sedimentary rocks from the Franklinian Mobile Belt, Melville Island, Canadian Arctic. Marine and Petroleum Geology, V. 10: 215-230.

Gentzis, T. and Goodarzi, F. (in press). Thermal maturation of organic matter in the Ellef Ringnes Island and surrounding area, Sverdrup basin. Energy Sources.

Gentzis, T. and Goodarzi, F. (in press). Regional maturation study of petroleum organic matter in the King Christian Island area, Canadian Arctic. Energy Sources.

Gentzis, T. and Goodarzi, F. (1993). Regional thermal maturity and hydrocarbon potential of the Mesozoic sediments in the Drake hydrocarbon field, Sverdrup Basin, Canadian Arctic. Journal of Petroleum Geology, V. 16, 1: 33-54.

Gentzis, T. and Goodarzi, F. (1992). Regional thermal maturity and source-rock potential in northwestern Melville Island, Canadian Arctic. Energy Sources, V. 14: 423-442.

Gentzis, T. and Goodarzi, F. (1992). The source-rock potential and thermal maturity of the sedimentary succession in the Drake and Hecla hydrocarbon fields, Melville Island, Canadian Arctic Archipelago. Norwegian Petroleum Society, special volume on 'Arctic Geology and Petroleum Potential', T.O. Vorren, E. Bergsager, O.A. Dahl-Stamnes, E. Holter, B. Johansen, E. Lie, and T.B. Lund (eds.). Publication No. 2, Elsevier Publishers B.V., Amsterdam, p.159-171.

Gentzis, T. and Goodarzi, F. (1991). Thermal maturity and source-rock potential of the sedimentary succession from the Hecla field in Sverdrup Basin, Canadian Arctic. International Journal of Coal Geology, V. 19: 483-517.

Gentzis, T. and Goodarzi, F. (1990). A review of the use of bitumen reflectance in hydrocarbon exploration with examples from Canadian Arctic. In: Applications of Thermal Maturity Studies to Energy Exploration, V.F. Nuccio and C.E. Barker (eds.). Rocky Mountain Section-Society of Economic Paleontologists and Mineralogists, Special Publication, p. 23-36.

Gentzis, T. and Goodarzi, F. (1991). Petrology and depositional environment and utilization potential of Devonian cannel coals from Melville Island, Canadian Arctic Islands. Bulletin of the Geological Society of France, V. 162, 2: 239-253.

Gentzis, T., Goodarzi, F. and Embry, A.F. (1996). Thermal maturation, potential source rocks and hydrocarbon generation in Mesozoic rocks, Lougheed Island area, central Canadian Arctic Archipelago. Marine and Petroleum Geology, V. 13, 8: 879-905.

Gentzis, T., Goodarzi, F. and Snowdon, L.R. (1993). Variation of maturity indicators (Optical and Rock-Eval) with respect to organic matter type and matrix lithology: An example from Melville Island, Canadian Arctic Archipelago. Marine and Petroleum Geology, V. 10: 507-513.

Gentzis, T., Goodarzi, F., Snowdon, L.R. and Fowler, M.G. (1991). Petrology and geochemistry of Canadian liptinite-rich coals. In: 1991 Abstracts of International Conference on Coal Science, Newcastle-upon-Tyne 16-20 September, 1991. Butterworth-Heinemann, Oxford, p. 51-157.

Goodarzi, F. and Gentzis, T. (1994). A brief study of the dispersed organic matter in Palaeozoic and Mesozoic strata from Melville Island, Canadian Arctic. In: Geological Reports, Melville Island, R.L. Christie and N.J. McMillan (eds.). Geological Survey of Canada, Bulletin 450: 215-222.

Goodarzi, F. and Stasiuk, L.D. (1988). Graptolite preparation for reflected light microscopy - technical note. In: Current Research Part A, Geological Survey of Canada, Paper 87-1A: 317-322.

Goodarzi, F. and Stasiuk, L.D. (1987). Amorphous kerogen: bituminite in the Second White Speckled shale, southern Saskatchewan. In: Current Research Part A, Geological Survey of Canada, Paper 87-1A: 349-352.

Goodarzi, F., Fowler, M.G. and Nassichuk, W.W. (1990). Organic geochemistry and organic petrology of Paleozoic oil shales in Canada. In: Proceedings of the 1989 Eastern Oil Shale Symposium Nov. 15-17, 1989, Institute for Mining and Minerals Research, University of Kentucky, p. 233-238.

Goodarzi, F., Gentzis, T., Jackson, G. and Macqueen, R.W. (1993). Optical characteristics of heat-affected bitumens from the Nanisivik mine, N.W. Baffin Island, Canadian Arctic. Energy Sources, V. 15: 359-376.

Goodarzi, F., Gentzis, T., Snowdon, L.R., Bustin, R.M., Feinstein, S. and Labonté, M. (1993). Effect of mineral matrix and seam thickness on reflectance of vitrinite in high to low-volatile bituminous coals: an enigma. Marine and Petroleum Geology, V. 10: 162-171.

Goodarzi, F., Gentzis, T., Harrison, J.C. and Thorsteinsson, R. (1992). Graptolite reflectance as indicator of thermal maturity of sedimentary rocks of Ordovician to Devonian age from the Queen Elizabeth Islands, Arctic Archipelago. Organic Geochemistry, V. 18, 3: 347-358.

Goodarzi, F., Gentzis, T., Embry, A.F., Osadetz, K.G., Skibo, D.N. and Stewart, K.R. (1992). Evaluation of maturity and source-rock potential in the Lougheed Island area of the Sverdrup Basin, Canadian Arctic. Norwegian Petroleum Society, special volume on "Arctic Geology and Petroleum Potential", T.O. Vorren, E. Bergsager, O.A. Dahl-Stamnes, E. Holter, B. Johansen, E. Lie and T.B. Lund (eds.). Publication No. 2, Elsevier Publishers B.V., Amsterdam, p.147-157.

Goodarzi, F., Fowler, M.G., Bustin, M. and McKirdy, D.M. (1992). Thermal maturity of Lower Paleozoic sediments as determined by the optical properties of marine-derived organic matter. In: Early Organic Evolution: Implications for Mineral and Energy Resources, M. Schidlowski et al. (eds.). Springer-Velag, Berlin, p. 279-295.

Goodarzi, F., Eskstrand, R., Stasiuk, L.D., Snowdon, L.R. and Williamson, B. (1991). Thermal metamorphism of bitumen of Archean Age by ultramafic volcanic flows from Ontario, Canada. International Journal of Coal Geology, V. 20: 56-70.

Goodarzi, F., Brooks, P.W. and Embry, A.F. (1989). Regional maturation as determined by organic petrology and geochemistry of Schei Point Group (Triassic) in the Western Sverdrup Basin, Canadian Arctic Archipelago. Marine and Petroleum Geology, V. 6: 290-302.

Goodarzi, F., Davies, G.R., Nassichuk, W.W. and Snowdon, L.R. (1988). Organic petrology and Rock Eval analysis of the Lower Carboniferous Emma Fiord Formation in Sverdrup Basin, Canadian Arctic Archipelago. Marine and Petroleum Geology, V. 4; 132-145.

Goodarzi, F., Davies, G.R., Nassichuk, W.W. and Snowdon, L.R. (1987). Exsudatinite in Carboniferous oil shale from Arctic Canada. Fuel, V. 66: 771-773.

Goodarzi, F., Gunther, P.R., Jenkins, W.A.M. and Snowdon, L.R. (1985). Preliminary organic petrography of Palaeozoic rocks from the Grand Banks, Newfoundland. Marine and Petroleum Geology, V. 4: 254-459.

Hamblin, A.P., Fowler, M.G., Utting, J., Hawkins, D. and Riediger, C.L. (1995). Sedimentology, palynology and source rock potential of Lower Carboniferous (Tournaisian) rocks, Conche area, Great Northern Peninsula, Newfoundland. Bulletin of Canadian Petroleum Geology, V. 43: 1-19.

Héroux, Y. et Chagnon, A. (1994). Pétrographie de la matières organiques et assemblages des minéraux des argiles du district minier et de la région de Pine-Point, Canada: une caractérisation des anomalies associées aux gîtes. Exploration and Mining Geology, V. 3: 53-65.

Héroux, Y. et Bertrand, R. (1991). Maturation thermique de la matière organique dans un bassin du Paléozoïque inférieur, basses-terres du Saint-Laurent, Québec, Canada: Canadian Journal of Earth Sciences, V. 28, 7: 1019-1030.

Héroux, Y. and Tassé, N. (1990). Organic-matter alteration in a early Paleozoic basin: Zonation around mineral showings compared to that around intrusions, St. Lawrence Lowlands, Quebec, Canada. Geological Society of America, Bulletin, V. 102: 877-888.

Héroux, Y. and Tassé, N. (1985). Pétrographie des grès de la Formation de York River du Canton de Galt. Ministère de l'Energie et des Ressources du Québec, Direction générale de la recherche géologique et minérale, MB-85-27, 29 p.

Héroux, Y., Chagnon, A. and Savard, M.M. (1996). Organic matter and clay anomalies associated with base-metal sulphide deposits: three case studies. GSA Meetings, Organics and Ore Deposits Symposium, Ore Geology Special Volume, Elsevier 11, p. 157-173.

Héroux, Y., Chagnon, A. et Savard, M. (1994). Anomalies des propriétés de la matière organique et des assemblages argileux associés au gîte de Pb-Zn de Gays River, Nouvelle-Écosse, Canada. Exploration and Mining Geology, V. 3, 1: 67-79.

Héroux, Y., Michoux, D., Desjardins, M. and Sangster, D. (1989). Pétrographie et géochimie des matières organiques des séquences plombo-zincifères d'âge carbonifère, Bassin de Salmon River, Nouvelle-Écosse, Canada. Organic Geochemistry, V. 14, 3: 253-268.

Héroux, Y., Chagnon, A., Dewing, K. and Rose, H.R. (in press). Organic matter and clay mineral assemblages of the Mississippi Valley-type Polaris ore deposit, Canadian Arctic. In: Organic Matter and Mineralization: Thermal Alteration, Hydrocarbon Generation and Role in Metallogenesis, M. Masterliz (ed.). Chapman and Hall, London.

Héroux, Y., Chagnon, A., Saint-Antoine, P. and Savard, M.M. (1994). Fluid migration and mineralization in the Lower Windsor Group, Nova Scotia: Organic Matter and Clay Assemblages from the Gays River, Jubilee and Walton Deposits. Nova Scotia Department Natural Resources, 18th Annual Review of Activities, Program and Summaries, p. 94-2.

Héroux, Y., Achab, A., Chagnon, A. and Bertrand, R. (1983). Evolution thermique de l'extrémité orientale de la péninsule de Gaspé, en relation avec les déformations tectoniques. Ministère de l'Energie et Ressources du Québec, Direction générale de la recherche géologique et minérale, DP-83-03, 90 p.

Héroux, Y., Bertrand, R., Chagnon, A., Connan, J., Pittion, J.L. and Kübler, B. (1981). Evolution thermique et potentiel pétroligène par l'étude des kérogènes des extraits organiques, des gaz adsorbés, des argiles, Karlsefni H-13 (offshore Labrador, Canada). Canadian Journal of Earth Sciences, V. 18, 12: 1856-1877.

Hunt, J.A. and Bustin, R.M. (1997). Thermal maturation and source rock potential of Cretaceous strata in the Collocating-Nechako region, south-central British Columbia, Bulletin of Canadian Petroleum Geology, V. 45: 239-248.

Kalkreuth, W.D., Riediger, C.L., McIntyre, D.J., Richardson, R.J.H., Fowler, M.G. and Marchioni, D. (1996). Petrological, palynological and geochemical characteristics of Eureka Sound Group coals (Stenkul Fiord, southern Ellesmere Island, Arctic Canada). International Journal of Coal Geology, V. 30: 151-182.

Kirste, D., Macqueen, R.W. and Goodarzi, F. (1989). Optical and compositional character of a diverse suite of natural bitumen from Middle Devonian carbonate rocks, Pine Point, Northwest Territories, Canada, and their paleothermal implication. Geological Survey of Canada, Special Arctic Frontier Geoscience Programme volume, Paper 89-1G; 51-55.

Kirste, D., Fowler, M.G., Goodarzi, F. and Macqueen, R.W. (1989). Optical and compositional characteristics and palaeothermal implications of a diverse suite of natural bitumens from Middle Devonian carbonate rocks, Pine Point, Northwest Territories. Geological Survey of Canada Current Research, Part G, Paper 88-1G: 51-55.

Leckie, D.A., Singh, C., Goodarzi, F. and Wall, J. (1990). Organic-rich, radioactive marine shale: A case study from the Cretaceous Shaftesbury Formation, Alberta, Canada. Journal of Sedimentary Petrology, V. 6: 101-117.

Link, C., Bustin, R.M., and Snowdon, L. (1989). Petroleum source potential of Phanerozoic strata in northern Yukon and Northwestern District of Mackenzie. Bulletin of Canadian Petroleum Geology, V. 37: 293-315.

Link, C. and Bustin, R.M. (1989). Organic maturation of Phanerozoic strata in Northern Yukon and Northwestern District of Mackenzie. Bulletin of Canadian Petroleum Geology, V. 37: 266-292.

Macauley, G., Fowler, M.G., Snowdon, L.R., Goodarzi, F. and Stasiuk, L.D. (1990). Ordovician oil shale source rock sediments in the central and eastern Canada mainland and eastern Arctic areas and their significance for frontier exploration. Geological Survey of Canada, Paper 90-14: 51 p.

Mastalerz, M., Thomson, M.L., Stankiewicz, A., Bustin, R.M., and Sinclair, A.J. (1994). A geochemical study of solid bitumen in an Eocene epithermal deposit; Owen Lake, B.C. Chemical Geology, V. 115: 249-262.

Mathews, W. H. and Bustin, R.M. (1985). Vitrinite reflectance of Eocene rocks of southern British Columbia. Canadian Journal of Earth Sciences, V. 22: 259-261.

Mukhopadhyay, P.K. (1989). Characterization of amorphous and other organic matter types by petrography and pyrolysis-gas chromatography. Organic Geochemistry, V. 14: 269-284.

Mukhopadhyay, P.K. and Wade, J.A. (1990). Organic facies and source rock potential of sediments from three Scotian Shelf wells. Bulletin of Canadian Petroleum Geology, V. 38, 4: 407-425.

Mukhopadhyay, P.K., Goodarzi, F., Kruge, M.A. and Alimi, M.H. (1997). Comparison of source rock geochemistry of selected rocks from the Schei Point Group and Ringnes Formation, Arctic Canada. International Journal of Coal Geology, V. 34: 225-260.

Mukhopadhyay, P.K., Wade, J.A. and Kruge, M.A.(1995). Organic facies and maturation of Cretaceous/Jurassic rocks, and possible oil-source rock correlation based on pyrolysis of asphaltenes, Scotian Basin, Canada. Organic Geochemistry, V. 22, 1: 85-104.

Mukhopadhyay, P.K., Wade, J.A. and Williamson, M. (1994). Measured versus predicted vitrinite reflectance from Scotian Basin wells: Implications for predicting hydrocarbon generation/migration. In: American Chemical Society Symposium Series Book: Vitrinite Reflectance as Maturity Parameter: Applications and Limitations, P.K. Mukhopadhyay and W.G. Dow (eds.). American Chemical Society Publication, Symposium Series Volume 570, Washington, D.C., p. 230-248.

Obermajer, M., Stasiuk, L.D., Fowler, M.G. and Osadetz, K.G. (in press). Application of the acritarch fluorescence in thermal maturity assessments. International Journal of Coal Geology.

Obermajer, M., Fowler, M.G., Goodarzi, F. and Snowdon, L.R. (1997). Organic petrology and organic geochemistry of Devonian black shales in southwestern Ontario, Canada. Organic Geochemistry, V. 26: 229-246.

Obermajer, M., Fowler, M.G., Goodarzi, F. and Snowdon, L.R. (1996). Assessing thermal maturity of Paleozoic rocks from reflectance of chitinozoa as constrained by geochemical indicators: an example from southern Ontario, Canada. Marine and Petroleum Geology, V. 13: 907-919.

Obermajer, M., Fowler, M.G., Goodarzi, F. and Snowdon, L.R. (1995). Petroleum potential of Devonian black shales in southwestern Ontario, Canada. In: Developments and Applications to Energy, Climate, Environment and Human History, J.O. Grimalt and C. Dorronsoro (eds.). Organic Geochemistry, p. 435-437.

Ogunyomi, O., Hesse, R. and Héroux, Y. (1980). Pre-orogenic and syn-orogenic diagenesis and anchimetamorphism in Lower Paleozoic continental margin sequences of the Northern Appalachians in and around Quebec City, Canada. Canadian Society of Petroleum Geologists, Bulletin, V. 28, 4: 559-577.

Ogunyomi, O., Hesse, R., Héroux, Y. and Chagnon, A. (1979) Thermal maturation of Lower Paleozoic shales in Northern Appalachian nappe structures around Quebec City, Canada. American Association of Petroleum Geologists, Bulletin, V. 63, 3: 504-505.

Pelechaty, S.M., Grotzinger, J.R., Goodarzi, F., Snowdon, L.R. and Stasiuk, L.D. (1988). Middle Proterozoic karst development and bitumen emplacement, Parry Bay Formation (Dolomite), Bathurst Inlet area, District of Mackenzie. In: Current Research, Part C, Geological Survey of Canada, Paper 88-1C: 299-312.

Potter, J., Richards, B.C., Morrow D.W. and Goodarzi, F. (1993). The Organic petrology and thermal maturity of Lower Carboniferous and Upper Devonian source rocks in the Liard Basin at Jackfish Gap-Yohin Ridge and North Beaver River, northern Canada: Implications for hydrocarbon exploration. Energy Sources, V. 15: 289-314.

Potter, J., Richards, B.C. and Cameron, A.R. (1993). The petrology and origin of coals from the Lower Carboniferous Mattson Formation, southwestern District of Mackenzie, Canada. International Journal of Coal Geology, V. 24: 113-140.

Randell, R.N., Héroux, Y., Chagnon, A. and Anderson, G.M. (1996). Organic matter and clay minerals at the Polaris Zn-Pb deposit, Canadian Arctic Archipelago. In: Carbonate-hosted Lead-zinc Deposit, D.F. Sangster (ed.). International Field Conference on Carbonate-Hosted Lead-Zinc Deposits, June 3-6, 1995, St. Louis, Missouri, USA. Society of Economic Geologists Special Publication, V. 4: 320-329.

Riediger, C.L. (1993). Solid bitumen reflectance and Rock-Eval Tmax as maturation indices: An example from the "Nordegg Member", Western Canada Sedimentary Basin. International Journal of Coal Geology, V. 22: 295-315.

Smith, M. and Bustin, R.M. (1996). A depositional model for the Late Devonian and Early Mississippian Bakken Formation, Williston Basin. Bulletin of Canadian Petroleum Geology, V. 44: 495-507.

Smith, W.D., St. Peter, C., Mukhopadhyay, P.K., Naylor, R.D., Ball, F.D., Kalkreuth, W.D. and Macauley, G. (1991). Composition and depositional environment of Eastern Canadian Oil Shales. International Journal of Coal Geology, V. 19: 385-438.

Stasiuk, L.D. (1997). The origin of pyrobitumens in Upper Devonian Leduc Formation gas reservoirs, Alberta, Canada: an optical and EDS study of oil to gas transformation. Marine and Petroleum Geology, V. 14: 915-929.

Stasiuk, L.D. (1996). Organic facies in black shale of Devonian-Mississippian Bakken Formation, southeastern Saskatchewan. In: Current Research, Part B, Geological Survey of Canada, Paper 1996-B, p. 15-22.

Stasiuk, L.D. (1994). Petrographic thermal maturity assessment of Winnipegosis (Middle Devonian) and Bakken (Devonian-Mississippian) Formations, Southeastern Saskatchewan. Bulletin of Canadian Petroleum Geology, V. 42: 178-186.

Stasiuk, L.D. (1994). Fluorescence properties of Paleozoic oil-prone alginite in relation to hydrocarbon generation, Williston Basin, Saskatchewan, Canada. Marine and Petroleum Geology, V. 11: 219-231.

Stasiuk, L.D. (1994). Oil-prone alginite macerals from organic-rich Mesozoic and Paleozoic strata, Saskatchewan, Canada. Marine and Petroleum Geology, V. 11: 208-218.

Stasiuk, L.D. (1993). Algal bloom episodes and the formation of bituminite and micrinite in hydrocarbon source rocks: evidence from the Devonian and Mississippian, northern Williston Basin. International Journal of Coal Geology, V. 24: 195-210.

Stasiuk, L.D. and Snowdon, L.R. (1997). Fluorescence micro-spectrometry of synthetic and natural hydrocarbon fluid inclusions: crude oil chemistry, density and application to petroleum migration. Applied Geochemistry, V. 12: 229-241.

Stasiuk, L.D. and Nassichuk, W.W. (1995). Thermal history and petrology of wood and other organic inclusions in kimberlite pipes at Lac de Gras, Northwest Territories. In: Current Research, Part B, Geological Survey of Canada, Paper 1995-B, p. 115-124.

Stasiuk, L.D. and Fowler, M.G. (1994). Hydrocarbon potential of Paleozoic hydrocarbon source rocks, Truro Island, Arctic Canada: organic petrology, organic geochemistry and thermal maturity. Bulletin of Canadian Petroleum Geology, V. 42: 419-431.

Stasiuk, L.D. and Osadetz, K.G. (1993). Thermal maturity, alginite-bitumen transformation, and hydrocarbon generation in Upper Ordovician source rocks, Saskatchewan, Canada. Energy Sources, V. 15: 205-237.

Stasiuk, L.D. and Osadetz, K.G. (1990). The life cycle and phyletic affinity of *Gloeocopsomorpha prisca* Zalesky 1917 from Ordovician rocks in Canadian Williston Basin. In: Current Research Part D, Geological Survey of Canada, Paper 89-1D: 123-137.

Stasiuk, L.D. and Goodarzi, F. (1988). Organic petrology of the Second White Speckled shale, Saskatchewan, Canada - A possible link between bituminite and biogenic gas. Bulletin of Canadian Petroleum Geology, V, 36: 397-406.

Stasiuk, L.D., Lockhart, G.D., Nassichuk, W.W. and Carlson, J.A. (in press). Thermal maturity evaluation of dispersed organic matter inclusions from kimberlite pipes, Lac de Gras, Northwest Territories, Canada. International Journal of Coal Geology.

Stasiuk, L.D., Goodarzi, F. and Fowler, M.G. (1994). Corpohuminite from Canadian Paleozoic source rocks: petrology and reflectance properties. In: Vitrinite Reflectance as a Maturity Parameter, Applications and Limitations, P.K. Mukhopadhyay and W.G. Dow (eds.). American Chemical Society Symposium Series 570, p. 52-63.

Stasiuk, L.D., Goodarzi, F. and Potter, J. (1993). Thermal maturity of Mesozoic strata, southern Saskatchewan. Bulletin of Canadian Petroleum Geology, V. 41: 218-231.

Stasiuk, L.D., Kybett, B.D. and Bend, S.L. (1993). Reflected light microscopy and transmission micro-FTIR of alginite in relation to petroleum generation, Upper Ordovician kukersites, Saskatchewan, Canada. Organic Geochemistry, V. 20: 707-719.

Stasiuk, L.D., Osadetz, K.G., Goodarzi, F. and Gentzis, T. (1991). Organic microfacies and basinal tectonic control on source rock accumulation; a microscopic approach with examples from an intracratonic and extensional basin. International Journal of Coal Geology, V. 19: 457- 481.

Stasiuk, L.D., Osadetz, K.G. and Goodarzi, F. (1988). Preliminary source rock evaluation of the Nordegg Member (Lower Jurassic), Alberta. In: Current Research, Part D, Geological Survey of Canada, Paper 88-1D: 51-56.

Vellutini, D. and Bustin, R.M. (1990). Organic maturation and thermal history of the Queen Charlotte Islands. Bulletin of Canadian Petroleum Geology, V. 38: 452-474.

Vellutini, D., Bustin, R.M. and Goodarzi, F. (1990). Source rock potential of Mesozoic and Tertiary strata, Queen Charlotte Islands, British Columbia. Bulletin of Canadian Petroleum Geology, V. 38: 440-451.

Wielens, J.B.W., vonder Dyck, H., Fowler, M.G., Brooks, P.W. and Monnier, F. (1990). Geochemical comparison of a Cambrian alginite potential source rock and hydrocarbons from the Colville/Tweed Lake area, Northwest Territories. Bulletin of Canadian Petroleum Geology, V. 38: 236-245.

APPENDIX

A History of the Society
Officers and Founding Members of the Society
Current members
Former members

A HISTORY OF THE SOCIETY

The Canadian Society for Coal Science and Organic Petrology, formerly known as The Canadian Coal Petrographers Group (CCPG), began with a group of petrographers working independantly in research groups within the Geological Survey of Canada, the Canada Centre for Mineral and Energy Technology (CANMET) and various steel companies, who had common interests in the growing role of coal petrography and coal carbonization. The first meeting of the Canadian Coal Petrographers Group was held at CANMET's Fuels Research Centre in Bells Corners, Ottawa, on June 25th, 1974. It was attended by thirteen delegates, including Jack Botham (CANMET), Alex Cameron (Geological Survey of Canada), Roger Donaldson (GSC), Allan Hampson (DOFASCO), Jon Jorgensen (CANMET), Doug Montgomery (CANMET), Bishu Nandi (CANMET), Paul Readyhough (STELCO) and Bob Zavitz (DOFASCO). Bob Zavitz was the chairman and Bishu Nandi was the secretary for this, and many subsequent meetings of the CCPG. The impetus for the meeting was to facilitate an exchange of information with regard to the role of bituminous coal macerals in carbonization. The application of coke strength predictions and the characteristics of Western Canadian coals became important aspects of subsequent meetings, as did fundamental problems with maceral identification. During this period, the CCPG began to meet on a regular basis and other distinguished petrographers, such as Peter Hacquebard and Terry Birmingham, joined the group.

During the early 1970s, most of the petrographic research in Canada was being carried out in laboratories of the Geological Survey of Canada (Institute of Sedimentary and Petroleum Geology, Calgary, Alberta) or the Canada Centre for Mineral and Energy Technology (CANMET, Bells Corners, Ottawa). At that time, the applications of coal petrography were already extending far beyond the realms of the bituminous coals and carbonization and into use of reflectance to identify regional coalification and metamorphic trends and environments of coal deposition. With the growing popularity and increased diversity of applications of coal petrography that developed during the 1980s, a new generation of "imported" and "home-grown" petrographers was spawned with interests in the petrography of coals of all ranks including peats, lignites, subbituminous coals and anthracites, sparking a major evaluation of Canada's coal resources. In 1975, a coal petrology laboratory was established by Peter Hacquebard at the Atlantic Geoscience Centre in Dartmouth, Nova Scotia and during the late 1970s and early 1980s, a number of coal petrology laboratories sprang up within the provincial geological surveys in British Columbia, Alberta, Quebec and Nova Scotia and at the universities of Regina, British Columbia and Western Ontario. Petrographers from Britain, Australia, Germany, Iran, India and the U.S.A. came to Canada and joined the ranks of the Canadian Coal Petrographers Group, contributing to the development of world-class coal and organic petrology research facilities. Membership in the CCPG swelled during this time, as did the variety of applications of coal petrography, which included studies in coal gasification, hydrogenation, pyrolysis, coal-oil and bitumen coprocessing, dispersed organic matter in sedimentary rocks, maturation trends in oil and gas prospecting, mineral matter and environmental aspects of coal petrography and geochemistry. The first and last parts of section I of the Atlas, (Coal Macerals and Carbonization Residues) reflects the unique nature and diverse uses of Canadian coals.

In 1990, the membership had reached a peak of about 65, and included associates from the U.S.A., Australia and New Zealand. At this time, the name was changed to "The Canadian Society for Coal Science and Organic Petrology" (CSCOP) to reflect the growing membership and diversity of interests, especially in the area of dispersed organic matter and the role of petrography in hydrocarbon source-rock evaluation, organic facies, hydrocarbon exploration and thermal maturity of sedimentary basins. This is reflected in the second part of the Atlas, which is devoted to organic matter in Canadian hydrocarbon source rocks.

The Society is a member of the Geoscience Council of Canada and many of our members have distinguished themselves internationally for their work on coal and the many other facets of coal and organic petrography. A technical and business meeting is held annually on a rotational basis across Canada. These meetings are commonly held in conjuction with those of other societies, particularly the Geological and Mineralogical Associations of Canada, to promote dialogue between the geologists, engineers and geochemists. A joint meeting between CSCOP and The Society for Organic Petrology (TSOP) was held in Calgary in 1990, (proceedings published in Organic Geochemistry, 1992, V.18, No. 3; J. Potter, D.L. Marchioni and F. Goodarzi (eds.)) and another will be held in Halifax in July 1998. In 1984, the Society co-sponsored the Annual Meeting of the International Committee for Coal Petrology (ICCP) in Calgary and has since hosted a number of successful symposia with internationally published proceedings. The first of these, the Hacquebard Symposium: Recent Advances in Coal and Organic Petrology and Geochemistry, was held in Calgary in 1990, (International Journal Coal Geology, V. 18, 1991; R.M. Bustin, A.R. Cameron and W.D. Kalkreuth (eds.)) in celebration of the distinguished career of Dr. P. A. Hacquebard, a pioneer in Canadian coal petrology. In May 1991, The Cameron Symposium: Advances in Organic Petrology and Geochemistry, (International Journal Coal Geology, 1993, V. 24, No. 1-4; R.M. Bustin and F. Goodarzi (eds.)) was held in Wolfville, Nova Scotia in recognition of the major contribution to coal geoscience in Canada by Dr. Alex Cameron, a founding member of the Canadian Coal Petrographers Group. In 1993, the Society sponsored a symposium on "Organic Petrology related to Fossil Fuels and Environmental Impact" in Edmonton (Energy Sources, 1995, V. 17, No. 1; F. Goodarzi (ed.)). To recognize and foster excellence in coal and organic petrology in Canada, the Society has established two merit awards in the names of these honoured members: the Hacquebard Award is presented to a member of the Society who has distinguished him- or herself internationally in coal science, and the Cameron Award is given to a student member who has demonstrated superior research capabilities in the field of organic petrology.

It is encouraging to note that the Society currently has a greater student membership than ever before in its history, despite the recent national and global decline in support for coal research. In contrast to the 1980s, much of the coal and organic petrology and applied petrology in Canada is being carried out by members in the private sector. By producing this volume, CSCOP has documented a legacy of research into the petrology of Canadian coal and organic matter as a celebration of the last 25 years of excellence in coal research in Canada. We hope it will serve as a foundation for future students of our natural energy resources and environment.

A.R. Cameron
J. Potter

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CANADIAN COAL PETROGRAPHERS GROUP

- **1974** Chairman: R. Zavitz, DOFASCO
  Vice-chairman: B.N. Nandi, CANMET
- **1978** Chairman: P.A. Hacquebard
  Secretary: A.R. Cameron
- **1982** Chairman: A.R. Cameron
  Secretary: R.M. Bustin
- **1986** Chairman: R.M. Bustin
  Secretary: J. Potter

CANADIAN SOCIETY FOR COAL SCIENCE AND ORGANIC PETROGRAPHY

- **1990** President: F. Goodarzi
  Secretary-Treasurer: J. Potter
- **1992** President: F. Goodarzi
  Secretary: J. Potter
  Treasurer: T. Gentzis
  Publications Editor: L.D. Stasiuk
- **1996** President: F. Goodarzi
  Secretary: M. Avery
  Treasurer: T. Gentzis
  Publications Editor: L.D. Stasiuk
- **1998** President: J. Potter
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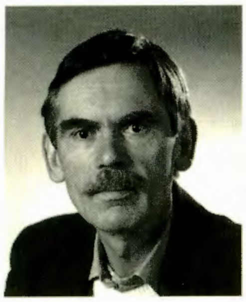

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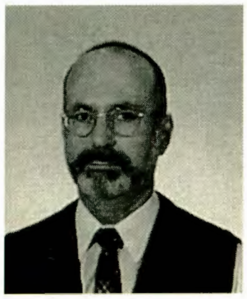

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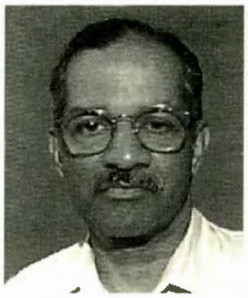

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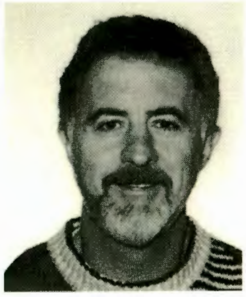

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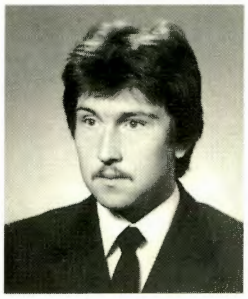

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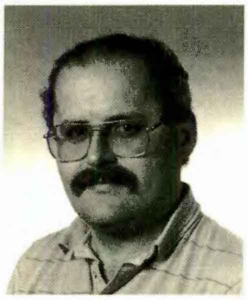

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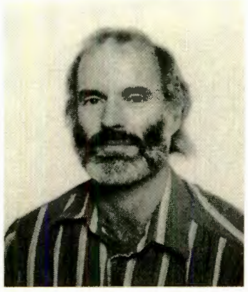

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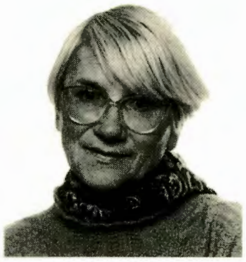

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