

# Geology of the Cumberland Basin, Cumberland, Colchester and Pictou Counties, Nova Scotia

R.J. Ryan and  
R.C. Boehner

Mines and Energy Branches  
Memoir 10

Nova Scotia



**Department of  
Natural Resources**



# Geology of the Cumberland Basin, Cumberland, Colchester and Pictou Counties, Nova Scotia

R.J. Ryan and  
R.C. Boehner

Mines and Energy Branches  
Memoir 10

Nova Scotia



---

**Department of  
Natural Resources**

Honourable Donald R. Downe  
Minister

Halifax, Nova Scotia  
1994

## Table of Contents

List of Figures, Enclosures and Maps .....	v
Abstract .....	xv
Chapter 1 - Introduction .....	1
Scope and Purpose of Study .....	1
Location and Access .....	1
Basin Nomenclature .....	1
Previous Work .....	4
Acknowledgments .....	5
Chapter 2 - Stratigraphy .....	7
Introduction .....	7
Carboniferous Stratigraphy .....	9
Formal Nomenclature .....	13
Chapter 3 - Paleontology .....	43
Introduction .....	43
Ichnology .....	43
Invertebrate Paleontology of Carbonates .....	46
Invertebrate Paleontology of Clastic Sedimentary Rocks .....	51
Vertebrate Paleontology .....	53
Conclusions .....	53
Chapter 4 - Sedimentology .....	57
Introduction .....	57
Sediment Dispersal Trends .....	57
Lithofacies, Lithofacies Associations, and Facies Assemblages .....	61
Chapter 5 - Structure and Basin Development .....	99
Introduction .....	99
Cobequid - Chedabucto Fault System .....	99
North Fault .....	101
The Cumberland Basin .....	104
Basin Development Structures .....	113
Cumberland Basin Development .....	116
Maritimes Basin Development .....	119
Chapter 6 - Thermal Evolution of the Cumberland Basin .....	129
Introduction .....	129
Vitrinite Reflectance .....	129
Thermal Alteration Index (Spore Coloration) .....	131
Apatite Fission Track Results .....	133
Burial History Plots .....	135
Interpretation .....	139

Chapter 7 - Mineral Resources of the Cumberland Basin	143
Introduction	143
Metallic Mineral Occurrences of the Cumberland Basin	143
Genetic Model for the Cumberland Basin Cu Occurrences	164
Exploration Model for the Cumberland Basin Cu Occurrences	169
Uranium Roll (Solution) Fronts	170
Paleoplacers	171
Industrial and Nonmetallic Minerals	174
Energy Resources	179
Chapter 8 - Conclusions	185
References	187
Appendix 1 - Palynology Summary	213

## List of Figures

### CHAPTER 1 INTRODUCTION

- Figure 1-1.** Regional location map, Maritimes Basin, Atlantic Canada. . . . . 2
- Figure 1-2.** General geology and location map, Cumberland Basin. . . . . 4

### CHAPTER 2 STRATIGRAPHY

- Figure 2-1.** Evolution of late Paleozoic stratigraphic nomenclature in the Cumberland Basin between 1845 and 1990. . . . . 8
- Figure 2-2.** Diagrammatic stratigraphy in the top eastern and bottom western parts of the Cumberland Basin. . . . . 11
- Figure 2-3.** General geology and location map of Windsor Group stratigraphic sections. . . . . 12
- Figure 2-4.** General correlation of the Viséan to Namurian Mabou and Windsor groups in the Cumberland Basin area. . . . . 13
- Figure 2-5.** Stratigraphy of the Windsor Group intersected in Pacific Fox Harbour drillhole C-96V. . . . . 16
- Figure 2-6.** Stratigraphy and general correlation of (Windsor Group) Lime-kiln Brook Formation sections with marine carbonates. . . . . 18
- Figure 2-7.** General geology and location of NSDME drillhole Lower Maccan LMA 88-1. . . . . 19
- Figure 2-8.** Detailed geology and location of NSDME drillhole Lower Maccan LMA 88-1. . . . . 20
- Figure 2-9.** North-south cross-section A-A<sub>1</sub> through NSDME drillhole Lower Maccan LMA 88-1. . . . . 21
- Figure 2-10.** Middleborough Formation type section in the Wallace River near Middleborough. . . . . 23
- Figure 2-11.** Summary of Upper Carboniferous lithostratigraphic nomenclature and correlation between northern Nova Scotia, Gulf of St. Lawrence area, and the Sydney Basin, Cape Breton Island. . . . . 25
- Figure 2-12.** General geology and index map of detailed type sections of Upper Carboniferous units in the Cumberland Basin. . . . . 26
- Figure 2-13.** Stratigraphy of the classic Joggins Section (adapted from Logan, 1845), type section of the Cumberland Group, Boss Point, Joggins and Ragged Reef formations; reference section of Claremont and Springhill Mines formations, and reference sections of the Mabou Group, Middleborough and Shepody formations. . . . . 27
- Figure 2-14.** Geology and location map with legend of the Joggins Section, the type section of the Cumberland Group, and reference sections of the Mabou Group, and Middleborough and Shepody formations. . . . . 28
- Figure 2-15.** Geological and location map, type section of the Polly Brook Formation and type areas of the Springhill Mines and Claremont formations. . . . . 31

<b>Figure 2-16.</b> Stratigraphy of the type section, Springhill Mines Formation, and type-reference sections of related units including the Polly Brook, Claremont and Boss Point formations. . . . .	33
<b>Figure 2-17.</b> Geological and location map, type section of the Malagash Formation near Malagash Point. . . . .	35
<b>Figure 2-18.</b> Stratigraphy of the type section, Malagash Formation. . . . .	36
<b>Figure 2-19.</b> Geology and location map, type section of the Pictou Group, River John. Note: Bell, 1944 originally included in the Pictou Group rocks now assigned to the Malagash Formation. . . . .	37
<b>Figure 2-20.</b> Composite stratigraphy of the Pictou Group type area, including the type section for the Cape John Formation, River John, Tatamagouche - Cape John area. . . . .	38
<b>Figure 2-21.</b> Geological and location map, type section of the Balfron and Tatamagouche formations, near Tatamagouche. . . . .	39
<b>Figure 2-22.</b> Stratigraphy of the type section, Balfron Formation. . . . .	40
<b>Figure 2-23.</b> Stratigraphy of the type section, Tatamagouche Formation. . . . .	41
<b>Figure 2-24.</b> Geological and location map, type section of the Cape John Formation, near River John. . . . .	42
 <b>CHAPTER 3 PALEONTOLOGY</b>	
<b>Figure 3-1.</b> Location map of the <i>Diplichnites</i> trails in the eastern Cumberland Basin. . . . .	44
<b>Figure 3-2.</b> (a) Photograph of the trails at Cape John, scale = 25 cm. (b) line drawing of the Cape John trails, scale = 25 cm. . . . .	45
<b>Figure 3-3.</b> Reconstruction of <i>Arthropleura</i> (after Briggs <i>et al.</i> , 1984; Ryan, 1986). . . . .	45
<b>Figure 3-4.</b> <i>Arthropleura</i> trails, lower surface, Smith Point, Cumberland County. . . . .	46
<b>Figure 3-5.</b> (a) Turning <i>Arthropleura</i> trail, upper trail surface, Smith Point, scale = 21 cm. (b) Line drawing of the same trail. . . . .	47
<b>Figure 3-6.</b> <i>Arthropleura</i> trails from Pugwash, scale = 21 cm. . . . .	47
<b>Figure 3-7.</b> Location map for paleontological study locations in the Cumberland Basin, Upper Carboniferous carbonates: (1) Melville Cove, (2) Murphy Point, (3) Louisville, (4) Chambers Point, (5) Malagash Point, (6) Treen Bluff, (7) Blockhouse Point, (8) Dewar River, (9) Lower Gulf Shore, (10) Pugwash, (11) South Shore Pugwash Bay, (12) Salisbury Point. . . . .	49
<b>Figure 3-8.</b> Drawing of <i>Paleochara acadica</i> , from Malagash Point locality. . . . .	51
<b>Figure 3-9.</b> Photomicrograph of <i>Garwoodia</i> sp? from Salisbury Point, identification verified by B. Mamet (pers. comm.). . . . .	52
<b>Figure 3-10.</b> Drawings of a possible <i>Lingula</i> mold from Salisbury Point. . . . .	53
<b>Figure 3-11.</b> Palynological sample distribution, Cumberland Basin, Nova Scotia. . . . .	55

## CHAPTER 4 SEDIMENTOLOGY

<b>Figure 4-1.</b> Paleocurrent - sediment dispersal trends in the Cumberland Basin, Nova Scotia. . . . .	58
<b>Figure 4-2.</b> Rose diagrams for paleocurrent measurements from the eastern part of the Cumberland Basin. . . . .	59
<b>Figure 4-3.</b> Photograph of unconformity, Malagash Formation overlying the overturned strata of the Windsor Group, demonstrating the syndepositional nature of diapirism, Dewar Hill Quarry south of Pugwash. . . . .	60
<b>Figure 4-4.</b> Cartoon illustrating the divergence of dispersal trends in the Cumberland Basin resulting from syndepositional diapirism. . . . .	60
<b>Figure 4-5.</b> Compilation of paleocurrent data from Devonian to Permian strata in the Maritimes Basin (after Ryan, 1986). . . . .	61
<b>Figure 4-6.</b> Paleodrainage patterns for Cumberland and Pictou group strata in the Maritimes Basin (after Gibling <i>et al.</i> , 1991). . . . .	62
<b>Figure 4-7.</b> Paleogeographic reconstruction of Upper Paleozoic drainage patterns in eastern North America, after Gibling <i>et al.</i> , 1991. . . . .	63
<b>Figure 4-8.</b> Transition matrices for the Boss Point Formation. . . . .	68
<b>Figure 4-9.</b> Transition matrices for the Joggins Formation. . . . .	69
<b>Figure 4-10.</b> Transition matrices for the Springhill Mines Formation. . . . .	69
<b>Figure 4-11.</b> Transition matrices for the Ragged Reef Formation. . . . .	70
<b>Figure 4-12.</b> Transition matrices for the Malagash Formation. . . . .	70
<b>Figure 4-13.</b> Transition matrices for the Balfron Formation. . . . .	72
<b>Figure 4-14.</b> Transition matrices for the Tatamagouche Formation. . . . .	73
<b>Figure 4-15.</b> Transition matrices for the Cape John Formation. . . . .	74
<b>Figure 4-16.</b> Lithofacies of the Boss Point and Claremont formations. . . . .	75
<b>Figure 4-17.</b> Lithofacies of the Boss Point Formation. . . . .	76
<b>Figure 4-18.</b> Lithofacies of the Polly Brook Formation. . . . .	77
<b>Figure 4-19.</b> Lithofacies of the Joggins Formation. . . . .	78
<b>Figure 4-20.</b> Lithofacies of the Springhill Mines Formation. . . . .	79
<b>Figure 4-21.</b> Lithofacies of the Ragged Reef Formation. . . . .	80
<b>Figure 4-22.</b> Lithofacies of the Malagash Formation. . . . .	81
<b>Figure 4-23.</b> Lithofacies of the Balfron Formation. . . . .	82



<b>Figure 4-24.</b> Lithofacies of the Tatamagouche Formation. . . . .	83
<b>Figure 4-25.</b> Lithofacies of the Cape John Formation. . . . .	84
<b>Figure 4-26.</b> Model for anastomosing stream after Galloway and Hobday (1983). . . . .	85
<b>Figure 4-27.</b> Revised anastomosing stream model after Smith and Smith (1980). . . . .	86
<b>Figure 4-28.</b> Graphic sinuosity index method (Ryan, 1986). . . . .	86
<b>Figure 4-29.</b> Drillhole and cross-section locations, Tatamagouche area, Nova Scotia. . . . .	88
<b>Figure 4-30.</b> Cross-section A-B, perpendicular to sediment dispersal trends. . . . .	89
<b>Figure 4-31.</b> Cross-sections C-D, and E-F, parallel to dispersal trends. . . . .	90
<b>Figure 4-32.</b> Composite(?) stream model, idealized section. . . . .	91
<b>Figure 4-33.</b> Composite stream model. . . . .	92
<b>Figure 4-34.</b> Braided stream model (Galloway and Hobday, 1983). . . . .	94
<b>Figure 4-35.</b> Alluvial fan model. . . . .	95
<b>Figure 4-36.</b> Meandering stream model. . . . .	96
<b>Figure 4-37.</b> Diagrammatic representation of depositional environments for the Pictou Group. The elevation of the Cobequid Mountains is greatly exaggerated. . . . .	97

## CHAPTER 5 STRUCTURE AND BASIN DEVELOPMENT

<b>Figure 5-1.</b> Location map of major structures in the Cumberland Basin. . . . .	99
<b>Figure 5-2.</b> Location map of structural features in the Cumberland Basin area. . . . .	100
<b>Figure 5-3.</b> Conglomerate units on the north and south side of the Cobequid Highlands Massif. . . . .	101
<b>Figure 5-4.</b> Cross-sections for the Cumberland Basin after Ryan <i>et al.</i> , 1990; for locations see Figure 5-2. . . . .	102
<b>Figure 5-5.</b> Structural classification of evaporite structures in Nova Scotia (after Boehner, 1986). . . . .	105
<b>Figure 5-6.</b> Location map of diapiric anticlines and isolated salt-cored domes. . . . .	106
<b>Figure 5-7.</b> Seismic interpretation for a line across the Claremont Anticline near Malagash, Nova Scotia. . . . .	109
<b>Figure 5-8.</b> Simplified geology, 630 Level in the Pugwash Mine (after Carter, 1990). . . . .	110
<b>Figure 5-9.</b> Simplified geology, 830 Level in the Pugwash Mine (after Carter, 1990). . . . .	111
<b>Figure 5-10.</b> Block diagram of the shaft anhydrite unit, Pugwash Mine (Carter, 1990). . . . .	112

<b>Figure 5-11.</b> Structure contour map on base of the Lucas salt bed with accompanying sections, Malagash Mine. . . . .	114
<b>Figure 5-12.</b> Geology and cross-section through the King Seaman Syncline near Minudie. . . . .	115
<b>Figure 5-13.</b> Rose diagrams of fault and joint strikes in the Cumberland Basin. . . . .	116
<b>Figure 5-14.</b> SeaSat image with linears from northwestern Nova Scotia. . . . .	117
<b>Figure 5-15.</b> Generalized stratigraphy of the Maritimes Basin. . . . .	118
<b>Figure 5-16.</b> Diagrammatic geology of Devonian to Namurian sedimentation represented by the Fountain Lake, Horton, Windsor and Mabou groups in the Cumberland Basin. . . . .	118
<b>Figure 5-17.</b> Diagrammatic geology of Devonian to early Westphalian sedimentation including the lower part of the Cumberland Group in the Cumberland Basin. . . . .	119
<b>Figure 5-18.</b> Diagrammatic geology of Devonian to middle Westphalian sedimentation including the Polly Brook, Joggins and Springhill Mines formations in the Cumberland Basin. . . . .	119
<b>Figure 5-19.</b> Diagrammatic geology of Devonian to late Westphalian sedimentation including the upper part of the Cumberland Group in the Cumberland Basin. . . . .	120
<b>Figure 5-20.</b> Diagrammatic geology of Devonian to Stephanian-Early Permian sedimentation of the Pictou Group in the Cumberland Basin. . . . .	121
<b>Figure 5-21.</b> Diagrammatic geology of the Pictou Group in the Cumberland Basin including late Permian to early Mesozoic tectonism. . . . .	121
<b>Figure 5-22.</b> Representative stratigraphic sections of Carboniferous basin fill adjacent to the Cobequid Highlands Massif illustrating the complex tectonic and sedimentation history through the Late Devonian to Stephanian-early Permian. . . . .	122
<b>Figure 5-23.</b> Evolution of sedimentation in the area of the Cobequid Highlands Massif through the Late Carboniferous (Namurian) to Stephanian-early Permian. . . . .	123
<b>Figure 5-24.</b> Late Paleozoic to early Mesozoic stratigraphy with interpreted subsidence history and megasequences in the Cumberland Basin area. . . . .	124
<b>Figure 5-25.</b> Basin classification scheme, after Kingston <i>et al.</i> , 1983. . . . .	125
<b>Figure 5-26.</b> Tectonic evolution of the Cumberland Basin, an example of a lateral wrench basin. . . . .	127
<b>Figure 5-27.</b> Perspective diagram illustrating the general structural setting of the Cumberland Basin adjacent to, and parallel with, the Cobequid - Chedabucto Fault System and the Cobequid Highlands Massif, and the resulting complexity related to block tilting in a lateral wrench basin environment. . . . .	128
 <b>CHAPTER 6 THERMAL EVOLUTION OF THE CUMBERLAND BASIN</b>	
<b>Figure 6-1.</b> Vitrinite reflectance values for northwestern mainland Nova Scotia. . . . .	130

<b>Figure 6-2.</b> Scatter plot of vitrinite reflectance (Ro% max) values versus age of the samples. Plot shows only a crude correlation. . . . .	130
<b>Figure 6-3.</b> Vitrinite reflectance histograms (all measurements) for three samples from the Cumberland Basin. The lower two samples have a few high reflectances which are probably the result of secondary oxidation. . . . .	131
<b>Figure 6-4.</b> Compilation of near-surface vitrinite reflectance values (Ro% max) for the Maritimes Basin (after Hacquebard and Donaldson, 1970; Mukhopadhyay, 1991b; Hyde <i>et al.</i> , 1991; and this study). . . . .	132
<b>Figure 6-5.</b> Histogram of vitrinite reflectance (Ro% max) for 286 near-surface localities from the Maritimes Basin. . . . .	133
<b>Figure 6-6.</b> Compilation of TAI (thermal alteration index) data for the Maritimes Basin. Data from Mukhopadhyay, 1991b; Dolby, 1987; Barss (various unpublished reports) and from company oil well reports. . . . .	134
<b>Figure 6-7.</b> Compilation of TAI (thermal alteration index) data for northwestern mainland Nova Scotia. Data from Mukhopadhyay 1991b, and this study. . . . .	135
<b>Figure 6-8.</b> Compilation of apatite fission track results for the Maritimes Basin (after Ryan, 1993). . . . .	136
<b>Figure 6-9.</b> Histogram of apatite fission track corrected ages for the Maritimes Basin. Two samples excluded from the plot are one high elevation sample from the Long Range in Newfoundland that was probably not covered in the Carboniferous and one sample from an oil well in the Gulf of St. Lawrence that has a young age due to depth in the well. The overall mean is approximately 232 Ma. . . . .	137
<b>Figure 6-10.</b> (a) Example of geological constraints used in the construction of burial history plots. The plot construction shown is for the Pictou Group strata in drillhole NT-47 in the Tatamagouche area in the eastern part of Cumberland Basin. (b) After construction of the time-burial path for the sampled horizon, the stratigraphic intervals are added to complete the burial history plots. . . . .	138
<b>Figure 6-11.</b> Burial history plot for the western Cumberland Basin as determined from data obtained from the South Athol drillhole SA-1. . . . .	139
<b>Figure 6-12.</b> Burial history plot for the central Cumberland Basin as determined from data obtained from the Oxford area drillhole BP-06. . . . .	139
<b>Figure 6-13.</b> Comparisons of Trac3 modelled distribution for track lengths of apatite fission tracks and their ages and the measured values for the Cumberland Basin samples and one sample from Hillsborough Bay, Prince Edward Island. The measured values can be predicted from the burial history plots for the various localities. . . . .	140
<b>Figure 6-14.</b> Diagrammatic representation of the possible Permo-Carboniferous sedimentary cover through time (after Ryan <i>et al.</i> , 1991). . . . .	141
 <b>CHAPTER 7 MINERAL RESOURCES OF THE CUMBERLAND BASIN</b>	
<b>Figure 7-1.</b> Metallic mineral occurrences of the Carboniferous basins of Nova Scotia. . . . .	143
<b>Figure 7-2.</b> Location map of industrial mineral occurrences in the Cumberland Basin. . . . .	144
<b>Figure 7-3.</b> Location map of metallic minerals in the Cumberland Basin. . . . .	145

<b>Figure 7-4.</b> Cartoon of the potential mineralization types that may occur in the Cumberland Basin. . . . .	146
<b>Figure 7-5.</b> Location and generalized geology of the Canfield Creek occurrence. . . . .	147
<b>Figure 7-6.</b> Detailed location map of the Canfield Creek deposit and a plot of the -230 mesh fraction of the regional till samples (after MacDonald <i>et al.</i> , 1992). . . . .	148
<b>Figure 7-7.</b> Location of drilling, trenches, and ore zone at the Canfield Creek deposit (after MacDonald <i>et al.</i> , 1992). . . . .	149
<b>Figure 7-8.</b> Cross-section of drillholes from the Canfield Creek Cu deposit. Note the upper pyrite with trace of sphalerite zone and the underlying Cu zone. . . . .	150
<b>Figure 7-9.</b> Core sample from ESSO drilling at Canfield Creek with disseminated chalcocite. . . . .	151
<b>Figure 7-10.</b> Core sample from ESSO drilling at Canfield Creek showing chalcocite nodules up to 2 cm in diameter. . . . .	151
<b>Figure 7-11.</b> Location and generalized geology of the Scotsburn copper occurrence. . . . .	152
<b>Figure 7-12.</b> Detailed section as exposed on the stream at the Scotsburn occurrence. . . . .	153
<b>Figure 7-13.</b> Stream geochemical anomalies associated with the Fitzpatrick Mountain fault, the Scotsburn occurrence. . . . .	154
<b>Figure 7-14.</b> Location and generalized geology of the Donaldson's Mill Brook occurrence. . . . .	154
<b>Figure 7-15.</b> Sketch of the mineralization at Donaldson's Mill Brook. . . . .	155
<b>Figure 7-16.</b> Permineralized plant cell structure, replaced by pyrite, chalcocite, and minor bornite, Oliver occurrence, French River. Note the detail that is preserved by the sulphide minerals. Some workers have argued that this proves that the copper mineralization was early diagenetic; however, only the pyrite need be early as the other minerals replaced pyrite. Py = pyrite, BO = bornite, CC = chalcocite, Dg = digenite. . . . .	155
<b>Figure 7-17.</b> Pyrite replaced by bornite and chalcocite, sample is from a chalcocite nodule from the Oliver Copper Mine, on French River. This sample is the exception to the rule, as there is perhaps a little late-stage pyrite present. Py = pyrite, BO = bornite, CC = chalcocite, Dg = digenite. . . . .	156
<b>Figure 7-18.</b> Exsolution features in pyrite and bornite, replaced by chalcocite and digenite. Py = pyrite, BO = bornite, CC = chalcocite, Dg = digenite. . . . .	156
<b>Figure 7-19.</b> Star-shaped blebs of bornite in a pyrite matrix, from large nodules collected at the Donaldson's Mill Brook occurrence; outer parts of the nodule are massive chalcocite. Py = pyrite, BO = bornite, CC = chalcocite, Dg = digenite. . . . .	157
<b>Figure 7-20.</b> Plot of sulphur isotopes contrasting the Tatamagouche (Cumberland Basin) occurrences with world class deposits. . . . .	158
<b>Figure 7-21.</b> Copper versus zinc for unmineralized red and grey sandstone. . . . .	159
<b>Figure 7-22.</b> Geochemistry of red (circles) vs. grey (squares) unmineralized sandstone; (a) Cu vs. SiO <sub>2</sub> (b) Zn vs. SiO <sub>2</sub> . . . . .	160

- Figure 7-23.** FeO vs. Fe<sub>2</sub>O<sub>3</sub> plot with grey sandstone as squares and red sandstone as circles; where values of the slope (S) are greater than 1.00 the rocks are grey, if they are less than 1.00 they are red. . . . . 160
- Figure 7-24.** Geochemistry of the Eatonville till in the Cumberland Basin. Dots are samples with 80% red clasts and circles are grey clast dominated, the line indicates the limits of the grey subset, and the boxes represent the mean and standard deviation for the red and grey populations. These plots show the same depletion of Cu+Zn for redbeds. . . . . 162
- Figure 7-25.** Plot of stream sediment geochemistry for streams in the Cumberland Basin. The stream sediment samples taken over redbeds show a depletion of Cu similar to the bedrock and till geochemistry. . . . 162
- Figure 7-26.** Catchment basin geochemistry plot of residual Cu-As. Note that although the Cumberland Basin area has numerous Cu occurrences the geochemical background is low (negative anomaly). . . . . 163
- Figure 7-27.** Drawing of quartz grain to matrix relationships in a typical red sandstone. Note that hematite never occurs between the quartz grain contacts, indicating a later diagenetic timing for the reddening. Q = quartz, H = hematite, R = rock fragment, P = plagioclase. Striped areas are fine clay matrix or primary porosity. . . . . 165
- Figure 7-28.** Cartoon of a cross-section of the Cumberland Basin indicating the relative position of basin saline brines and meteoric water interface. Cartoons show that there is an infiltration of oxygenated groundwater entering porous sandstones, which reddens them except for the carbon-rich lags at the base of the channel sequences. . . . . 166
- Figure 7-29.** Possible paleogeographic reconstruction of the Cumberland Basin in the late Permian, looking southwest. Note the infiltration of the oxygenated water and the possible mixing with chlorine-rich salt springs. . . . . 167
- Figure 7-30.** Sandstone-hosted redbed Cu occurrence with the reddened strata and the concentration of Cu-Ag-Zn, etc., at the interface with the local reduced beds at the channel lag or with overlying grey organic and pyrite-rich mudstone. . . . . 168
- Figure 7-31.** Cartoon depicting the possible origin of the shale-hosted redbed copper occurrences in the Cumberland Basin. . . . . 169
- Figure 7-32.** Exploration model for the sandstone-hosted redbed, Cu deposits of the Cumberland Basin: (a) large scale overview of the redox boundary with the various geochemical responses; (b) a close up view of the redox boundary depicting the remobilization of the chalcophile elements to the redox front or interface. . . . . 170
- Figure 7-33.** Possible location of a uranium roll front in the Port Phillip area. Drillholes have gamma ray responses typical of backtails (updip from roll front) and remote seepage zones (downdip from roll fronts). The roll front possibly occurs between these drillholes. . . . . 172
- Figure 7-34.** Schematic representation of the development of secondary roll fronts within channel sequences in the Cumberland Basin. . . . . 172
- Figure 7-35.** Gold occurrences and sediment dispersal patterns for northern Nova Scotia (after Ryan *et al.*, 1988). Triangles = Au occurrences, circles = Sn occurrences, and arrows indicate Carboniferous paleoflow directions. . . . . 173
- Figure 7-36.** Weighted fine fraction Sn values for tills in the Cumberland Basin - Cobequid Highlands Massif areas. Note that the high tin values extend into the basin although the till moved predominately southward. This indicates a Carboniferous source for the Sn values (after Ryan *et al.*, 1988). . . . . 174

<b>Figure 7-37.</b> Cartoon model for tin paleoplacer concentration in the basin fill strata of the Cumberland Basin (after Ryan <i>et al.</i> , 1988). . . . .	175
<b>Figure 7-38.</b> Plot of the Au stream geochemistry and mineral occurrences for the Cumberland Basin. The Au anomalies closely correspond to outcrops of conglomeratic strata. . . . .	176
<b>Figure 7-39.</b> Photographs of the celestite - galena occurrences at Beckwith. The celestite appears to be crystallizing in a clay hydration zone between the evaporates and Upper Carboniferous strata that are in fault contact with each other. . . . .	177
<b>Figure 7-40.</b> Energy resource occurrences in the Cumberland Basin. . . . .	180

## ENCLOSURES AND MAPS (REAR POCKET)

**Enclosure 1.** Stratigraphy of the Joggins area, Nova Scotia; Nova Scotia Department of Natural Resources Open File Illustration 90-001.

**Enclosure 2.** Stratigraphy of the Springhill area, Cumberland Basin.

**Enclosure 3.** Stratigraphy of the French River - River John section; Nova Scotia Department of Natural Resources Open File Illustration 90-002.

**Enclosure 4.** Detailed drillhole correlation - Oxford area, Nova Scotia; Nova Scotia Department of Natural Resources Open File Illustration 90-003.

**Enclosure 5.** Detailed drillhole correlation - Tatamagouche area, Nova Scotia; Nova Scotia Department of Natural Resources Open File Illustration 90-004.

**Map 90-11.** Cumberland Basin Geology Map, Apple River and Cape Chignecto, Cumberland County, scale 1:50 000.

**Map 90-12.** Cumberland Basin Geology Map, Amherst, Springhill and Parrsboro, Cumberland County, scale 1:50 000.

**Map 90-13.** Cumberland Basin Geology Map, Oxford and Pugwash, Cumberland County, scale 1:50 000.

**Map 90-14.** Cumberland Basin Geology Map, Tatamagouche and Malgash, Cumberland, Colchester and Pictou Counties, scale 1:50 000.