Chapter 1 - Introduction

Scope and Purpose of Study

This geological study of the Carboniferous to Permian strata of the Cumberland Basin, Nova Scotia, was undertaken from 1983 to 1988 as part of the Canada - Nova Scotia Mineral Development Agreement (1984-1989) and was funded by the Province of Nova Scotia. The primary objective was to gain a modern, comprehensive understanding of the stratigraphy, sedimentology, structure, economic geology and basin development history of the Cumberland Basin, as support for evaluating the area's potential for mineral and energy resources.

The study included: (1) mapping the entire area at a scale of 1:10 000 (NSDME Open File Maps 88-39 to 88-43), with four published maps in colour at a scale of 1:50 000 (NSDME Maps 90-11 to 90-14, rear pocket); (2) logging 16 000 m of core from more than one hundred diamond-drill holes; (3) measuring, describing and sampling outcrop sections at representative sites throughout the area; (4) measuring over 1500 paleocurrent indicators; (5) interpreting airphoto, remote sensing, seismic and geophysical data for the basin; (6) petrographic studies of one hundred representative thin sections from the various lithofacies; (7) paleontological collection and identification; (8) detailed mapping and lithogeochemical study of 40 mineral occurrences; (9) polished section petrography of mineralized samples; (10) fluid inclusion, vitrinite reflectance, clay mineralogy, and sulphur isotope studies of the various mineralization types; (11) chemical analysis of the unmineralized strata in the Cumberland Basin; and (12) cooperative incorporation of available concurrent work by the Geological Survey of Canada and the Nova Scotia Department of Natural Resources, Mineral Development Division and Energy Resources Division.

The investigations were designed to: (1) determine the stratigraphy of the basin and propose more detailed lithostratigraphic subdivision where possible; (2) produce up-to-date geological maps; (3) investigate the sedimentological and overall diagenetic history of the strata; (4) determine the sediment dispersal trends and provenance; (5) integrate the available surface and subsurface data; (6) derive a basin development model(s); and (7) determine and promote the economic potential of the numerous mineral and energy resource occurrences in the Cumberland Basin.

Location and Access

The study concentrated on the Permo-Carboniferous strata of the Cumberland Basin (Fig. 1-1) which is located north of the Cobequid Highlands in northern Nova Scotia, Canada. The study area extends from River John in the east, to Cape Chignecto approximately 150 km to the west. The Cobequid Highlands, Chignecto Bay and the Northumberland Strait coastline define the southern, northwestern and northeastern limits of the study area, respectively. This 3500 km^2 area is bounded approximately by 45°20' and 46°00'N latitude and 63°00' and 64°50'W longitude and lies within National Topographic System map sheets 11E/11, 12, 13 and 14, and 21H/7, 8, 9, 10 and 16. Four geological maps of the area, in colour (Ryan *et al.*, 1990), are included in the pocket.

Access is by Trans-Canada Highway 104 and numerous secondary roads, as well as crown land and forestry access roads. Major rivers can be navigated by canoe and provide access to the inland areas. In addition, access to the shoreline can be gained either on foot or by boat along the Northumberland Strait and Chignecto Bay shorelines.

Basin Nomenclature

Introduction

The confusion in terminology applied to upper Paleozoic basins in Atlantic Canada arises from numerous, rapidly changing sedimentological and tectonic models of basin evolution. Boehner *et al.* (1988a) consider the following as major contributors to the confusion: (1) vague definition of names; (2) subsequent redefinition, often of a radical nature; (3) mixed terminology; (4) conflicting interpretations; and (5) excessive generalization. These authors believe that genetic nomenclature, based on the sedimentological or tectonic characteristics of the basin, are subject to re-interpretation and, therefore, to repeated revision. Constant revisions of definitions and names leads to a confusing abundance of terminology referring, in many instances, to the same geographic area. Boehner *et al.* (1988a) recommend usage of non-genetic terms whenever possible in order to provide continuity and limit future revisions; furthermore, they suggest that genetic nomenclature should be used as a separate independent level of terminology which may be applied

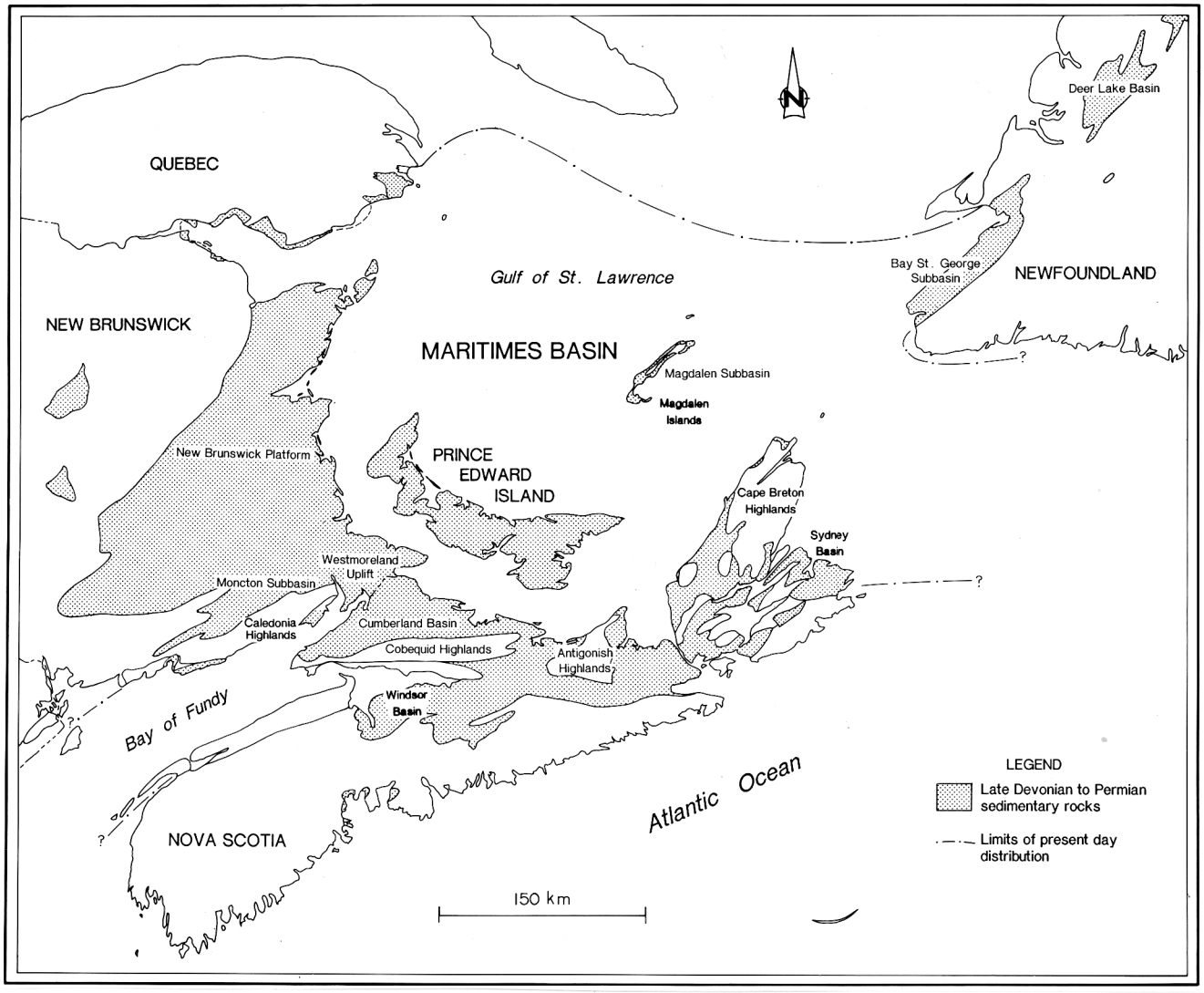

Figure 1-1. Regional location map, Maritimes Basin, Atlantic Canada.

to the entire basin or any part thereof. Ideally, non-genetic names should reflect the following: (1) present-day features, (2) age of the strata, (3) use of the term "basin" as referring to a complex or system, (4) use of a non-genetic name as a general reference, and (5) use of an exclusive identifier which should not be used as part of a genetic term applied in all or part of the same area. Use of terms in this context should eliminate the need for repeated revisions of basin nomenclature.

The Maritimes Basin (Composite Basin)

The Paleozoic of the Atlantic region is represented by a folded belt of sedimentary, metamorphic and igneous rocks which constitute the northeastern part of the Appalachians. The earliest folding of Paleozoic strata in the Atlantic region took place during the Ordovician Taconic Orogeny. Subsequent folding, faulting, intrusion and metamorphism during the Devonian Acadian Orogeny stabilized the Appalachian 'geosyncline', which presently extends to the edge of the continental shelf (Poole, 1967). The Permo-Carboniferous of eastern Canada is represented by a successor basin system comprising a post-Acadian molassic suite of coarse- and fine-grained terrestrial siliciclastics and subordinate shallow marine clastic, carbonate, evaporite, and volcanic rocks. It underlies an irregular area of lowland extending from the Bay of Fundy through the Gulf of St. Lawrence to offshore Newfoundland. The onshore distribution extends from eastern Maine to Newfoundland and southern mainland Nova Scotia to northern New Brunswick (Fig. 1-1). The original extent of Permo-

Carboniferous strata remains uncertain, as the present distribution of these rocks is only an erosional remnant of a much larger basin that probably covered most of New England and Atlantic Canada (van de Poll, 1973).

Many names, as well as numerous tectonic and genetic interpretations, have been applied to the major area of Permo-Carboniferous rocks in Atlantic Canada, including: (1) Fundy Basin (Bell, 1958); (2) Fundy Geosyncline (Bell, 1944; Belt, 1968a, 1968b); (3) Fundy Epieugeosyncline (Poole *et al.*, 1970); (4) Maritimes Basin (Roliff, 1962); (5) Fundy Aulacogen (Keppie, 1977); (6) Magdalen Pull-apart Basin (Bradley, 1982); (7) Pictou-Morien Foreland Basins (Keppie, 1982a, 1982b); and (8) Gulf of St. Lawrence (Coal) Basin (Hacquebard, 1986), as well as many others. The basin name with the most consistent application, predominantly in a non-genetic sense, over the past 25 years has been 'Maritimes Basin', a term used by Roliff (1962) to encompass all Carboniferous strata in Atlantic Canada. Boehner *et al.* (1988a), following the practice of Knight (1983) and Carter and Pickerill (1985a), recommend use of the name 'Maritimes Basin' (Roliff, 1962), as a non-genetic term applicable, in the geographic sense, to all upper Paleozoic rocks in Atlantic Canada. The term 'Maritimes Basin' is used as a non-genetic term throughout this report.

Van de Poll and Ryan (1985) suggest that the Maritimes Basin (Fig. 1-1) should not be thought of as a single post-orogenic basin, but rather as a "composite basin", consisting of a group of interconnected fault block basins and horsts which at various times underwent differing rates of subsidence and uplift. Fragmentation of the Acadian Orogen into the New Brunswick Platform, various sub-basins, Nova Scotia Platform, and the Newfoundland Platform established a set of tectonic elements that prevailed into the Permian (Howie and Barss, 1975). Continuing fragmentation of the main depositional basin into structural basins (subbasins) took place along a series of faults both during and after basin development. In different areas of the Maritimes Basin these have been interpreted as high-angle normal and reverse faults (Gussow, 1953), rotational faults (van de Poll, 1970), wrench faults and thrusts (Webb, 1969; Belt, 1968b), or possibly transform faults (Bradley, 1982). Details of the fault movement history are not well defined and continue to be the subject of divergent interpretations both at the local and regional scale.

The Cumberland Basin

For the purpose of clarity, the term 'Cumberland Basin' will be used in this study as a non-genetic term to define the thick accumulation of Late Devonian to Early Permian strata occurring in northwestern Nova Scotia and southeastern New Brunswick (Fig. 1-2). Bell (1944, p. 1) first defined the Cumberland Basin as delineating a basin of Carboniferous deposition in northern Nova Scotia and southern New Brunswick, contained within the "Fundy Geosyncline" (= Maritimes Basin):

> "The two coalfields"... Joggins - River Hebert and Springhill... "belong to a single basin of deposition, the Cumberland basin, which lies within a larger geosynclinal area of Carboniferous sedimentation that may be designated the Fundy geosyncline. The Cumberland basin is bounded on the west by the crystalline rocks, mainly Precambrian, of the Caledonia upland of southern New Brunswick, and on the south by the crystalline rocks and altered sediments, Silurian and later, of the Cobequid upland of Nova Scotia. The eastern boundary is formed by the McLellan - Brown upland of Pictou and Antigonish Counties. The northern boundary of the basin cannot from present knowledge be defined, for it apparently lies beneath a cover of sediments of late Upper Carboniferous (Pennsylvanian) age".

Using Bell's definition, the Cumberland Basin constitutes a large basin (or subbasin) which forms part of the larger Maritimes Basin in an area north of the Minas Geofracture (Cobequid - Chedabucto Fault System) (Fig. 1-2).

Bell (1958) subsequently made reference to a "Cobequid subsiding basin of deposition" comprising two sub-basins, the Cumberland basin to the north and the Minas basin to the south. They were interrupted by the Cobequid and Pictou - Antigonish uplands. He further observed that the Cobequid upland had a complex geomorphological history and may not have been an influencing feature during the time of Windsor Group and perhaps Horton Group deposition.

The Cumberland Basin is an east-west depocentre that contains a succession of sedimentary strata in excess of 7 km thick. Most of the basin fill is terrestrial, except for one marine succession of Early Carboniferous age (Viséan Windsor Group). The Cumberland Basin, as defined for this study, is bordered as follows: on the south side by the Cobequid Highlands Massif; on the north side by the Northumberland Strait (exact limits are unknown); on the east side by the axis of the Scotsburn

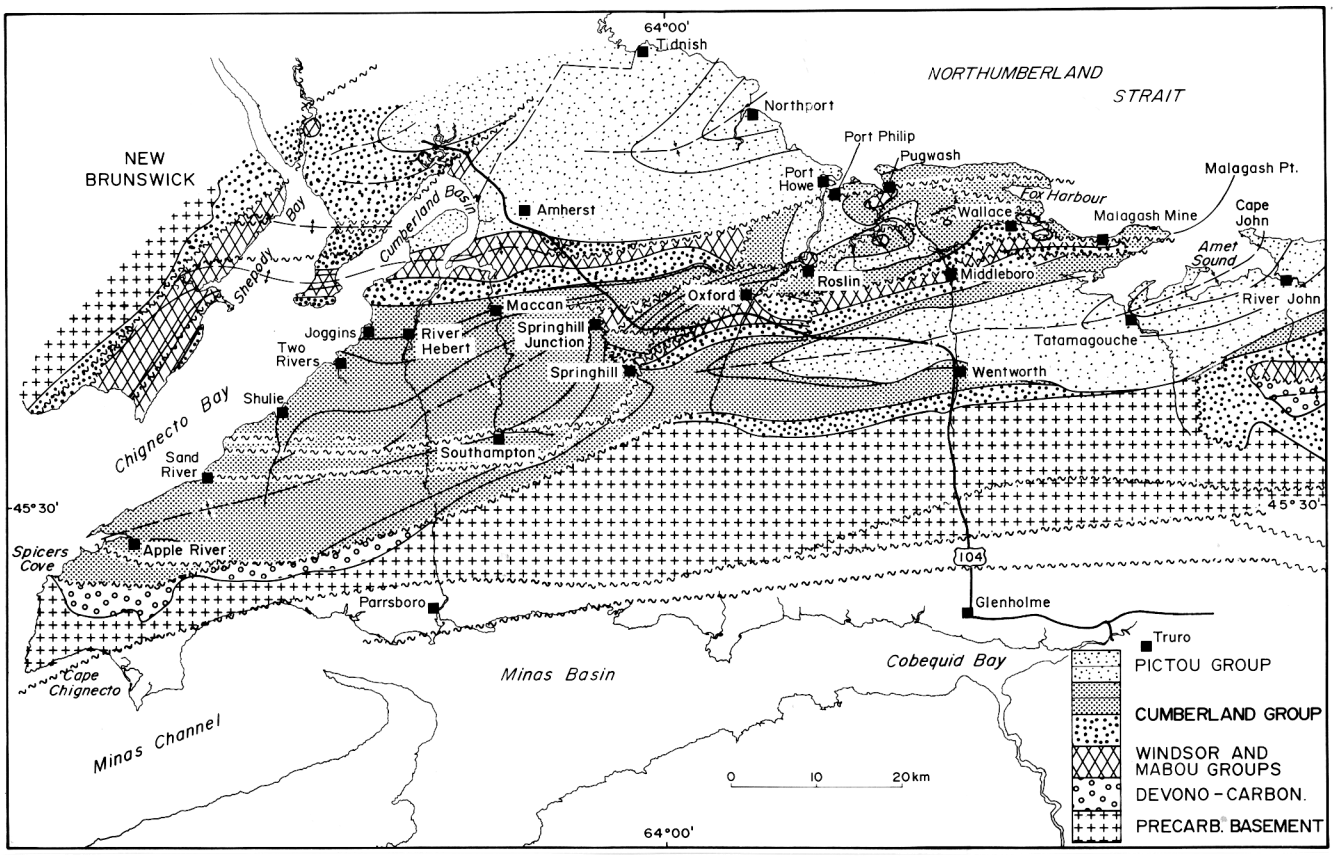

Figure 1-2. General geology and location map, Cumberland Basin.

Anticline, rather than the Antigonish Highlands as indicated by Bell (1944); and on the west side by the Caledonia Highlands Massif and Westmorland Uplift (Fig. 1-2). The exclusion of the eastern part of the basin as defined by Bell (1944) follows the nomenclature of numerous recent workers who refer to that area as the 'Stellarton Graben' or 'Stellarton Gap'.

The internal structure of the Cumberland Basin is generalized as a broad, east- to northeast-trending synclinorium that encloses two parallel, diapiric anticlinal structures, the Claremont - Malagash and Minudie anticlines. Major synclines occurring in the basin are the Athol, Tatamagouche, Amherst and Wallace synclines. The internal structure of the Wallace Syncline is complicated by faults and several isolated salt domes up to 3 km in diameter.

Upper Carboniferous to Lower Permian terrestrial sedimentary rocks are exposed at surface throughout most of the basin. Progressive and complicated onlap of these younger units onto the basin margins limits the exposure of older strata. The pre-Namurian strata are limited to exposure in axial regions of the diapiric anticlines and domes.

The Cumberland Basin has a long history of coal and salt mining, and contains numerous metallic and industrial mineral occurrences. The basin also has potential for oil and gas deposits.

Previous Work

The first geological investigations of the Cumberland Basin were by Alger and Jackson (1828). Brown and Smith (1829) evaluated the coal resource potential, described some of the shoreline sections in the western part of the basin, and remarked on the similarity to the British Carboniferous. Gesner (1836) investigated the Springhill region and made the initial documentation of coal seams. Lyell (1845) described in detail fossils collected from the coastal section between Minudie and Joggins. Logan (1845) measured the strata exposed along the shore at Joggins bed-by-bed. Although wave action and erosion have slightly altered the section exposed along the Joggins shore, his detailed

observations are still very representative of the strata exposed today. Logan divided the section into eight divisions based on lithology, colour, and the abundance of coal seams.

Dawson (1855) examined and identified much of the biota of Logan's section and attempted to infer paleo-environmental settings. Ells (1885) was the first geologist to synthesize the geology of northern Nova Scotia and southern New Brunswick into a map. In 1892, Fletcher began his sixteen year study of the geology of the Cumberland Basin and died while doing field work along the Joggins shore at Lower Cove in 1908 (Shaw, 1951a, 1951b). Fletcher (1892-1909) published a series of geological maps for the area. He also augmented Logan's original Joggins section by including descriptions of strata to the south.

Bell's studies of the strata in northern Nova Scotia started in 1912 and continued for many years (Bell, 1912, 1924, 1927, 1944, 1958). Many of his observations from the Cumberland Basin were critical to the establishment of stratigraphic nomenclature for Carboniferous rocks in the Cumberland Basin, as well as much of the Maritimes Basin. Shaw (1951a) made the initial attempt at basin analysis in the Cumberland Basin. His observations of facies variations within the strata, and the map division terminology that he introduced, were generally accepted when this study was initiated. Copeland (1957) re-examined and extended the work of Shaw (1951a) and made refinements in stratigraphy based on paleontology in the western part of the Basin.

Howie and Cumming (1963) used the depth to basement as a method to define basin structure. Howie and Barss (1975b) used similar geophysical data and methodology to create isopachs of the various stratigraphic units in Atlantic Canada and these data have been applied to the thickness of sediment accumulation to define the various onland and offshore basins of Atlantic Canada. Palynology was used by Hacquebard and Donaldson (1964) and later Hacquebard (1972, 1986) and Barss and Hacquebard (1967) to establish and refine the age relationships of the various lithostratigraphic units.

During the past thirty years, many workers have made significant contributions to the understanding of the stratigraphy and sedimentology of Carboniferous strata in northern Nova Scotia. Amongst these are: Gillis (1964) in the eastern Cumberland Basin; Belt (1964, 1965, 1968b) on lateral variations on a regional scale; Kelley (1967) on the regional aspects of stratigraphic nomenclature; Walton and Duff (1973) on the sedimentology of the Joggins section; Calder (1991) on the Cumberland Group in the Springhill, Joggins and River Hebert area; van de Poll and Ryan (1985) on the stratigraphy and sedimentology of the Carboniferous - Permian transition; Rust *et al.* (1984) on the fluvial style of sedimentation in the western part of the Cumberland Basin; and Salas (1986) on the sedimentology in the Apple River area of the western Cumberland Basin. Ryan *et al.* (1991) proposed new and revised stratigraphic nomenclature for the Upper Carboniferous to Lower Permian strata in the Cumberland Basin and outlined the regional implications for the Maritimes Basin.

Structural geology and sedimentation in response to tectonic movements has been the subject of many studies in recent years (see Howie, 1986, 1988). Eisbacher (1967) published the first comprehensive work on kinematics of faulting along the Cobequid Fault system adjacent to the Cumberland Basin. Partly on the basis of Eisbacher's (1967) interpretation that fault movement represented a large strike-slip system, Webb (1969) proposed that the Maritimes Basin was formed as a large wrench basin. Fyson (1967) examined the topic of gravity sliding and cross folding in northern Nova Scotia, relating overturned folds to uplift and gravity sliding. White (1972) discussed the concept that the Cumberland Basin was a rift basin using seismic data and basin fill characteristics. Bradley (1982) and Keppie (1982a) suggested a pull-apart origin and Keppie (1982a) further proposed that this initial pull-apart phase was followed by a foreland basin phase. Fralick (1980), Fralick and Schenk (1981), Donohoe and Wallace (1985), Yeo and Ruixiang (1986), and Ryan *et al.* (1987) examined the distribution of facies within the basins of northern Nova Scotia and proposed possible models of strike-slip basin development.

Significant contributions to the understanding of the economic geology of Upper Carboniferous rocks in the region were made by Messervey (1929), Papenfus (1931), Shumway (1951), Brummer (1958), MacKay and Zentilli (1976), Dunsmore (1977a, 1977b), Kirkham (1978) and van de Poll (1970). In addition, unpublished exploration assessment reports by geologists working for numerous mineral and energy exploration companies, including Noranda, Lacana, Esso, British Petroleum and others, contain important data on drilling programs.

Acknowledgments

This report and its accompanying maps, as well as previous related publications (e.g. Ryan *et al.*, 1991),

have benefitted greatly from encouragement, discussion, review and revisions suggested by many co-workers and contemporary workers in the Maritimes Basin including: Edward Belt, Howard Donohoe, Martin Gibling, Peter Giles, Alan Grant, Peter Hacquebard, Robert Howie, Robert Naylor, Guy Plint, Walter van de Poll, Marcos Zentilli and Gary Yeo. This does not necessarily imply agreement with the map interpretations or stratigraphic revisions, for which the authors are solely responsible. The informal and formal input by these individuals has been invaluable in defining the evolution of the stratigraphic nomenclature, philosophical aspects of potential revision strategies, and ultimately the revisions presented in Ryan *et al.* (1991) and in this report. We are greatly indebted to earlier workers, especially W. A. Bell. Bell developed the basic stratigraphic framework, with remarkable accuracy in correlation and understanding, upon which all subsequent stratigraphic work and revision has been based.

Re-mapping and interpretation of the geology in the Cumberland Basin were facilitated by substantial contributions from unpublished and published maps, papers, reports, notes and communications by numerous previous workers including: W. A. Bell, H. Fletcher, W. Logan, C. Lyell, J. W. Dawson, M. Copeland, W. Shaw, W. Roliff *et al.* with Imperial Oil, R. Howie and W. Gillis. Contributions of unpublished material by J. H. Calder (Springhill), R. Naylor, G. Somers, D. Carter, P. Watson, F. Chandler and H. Donohoe are gratefully acknowledged.

The geology of the Springhill Coalfield was compiled from Calder (1990). Cobequid Highlands geology was compiled and/or modified after Donohoe and Wallace (1982) and unpublished Geological Survey of Canada field maps by D. G. Kelly (1974). Mapping in the Tatamagouche Syncline area (NTS 11E/11, 11E/12) was based on Ryan (1986c). Map units and lithostratigraphy on Maps 90-11 to 90-14 supersede those on the Preliminary Geological Field Maps of the Cumberland Basin (one hundred one, 1:10 000 scale map sheets) released as NSDME Open File Maps 88-39 to 88-42 (Ryan *et al.*, 1988b).

The field work component of the Cumberland Basin Project, undertaken between 1985 and 1988, was supported by field assistants M. Black, J. Chisholm, V. Clifford, B. Cox, A. Deal, K. Deveau, T. Milburn and A. Stark.

This memoir was edited by Doug MacDonald. Barb MacDonald carried out the tasks of word processing and page layout. Cartography and photography were ably handled by Joe Campbell, Wayne Burt, Phil Belliveau, Cynthia Phillips, Jim DeWolfe, Patti Fraser, Janet Webster, Reg Morrison and Carol Murphy.