CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

GEOLOGICAL SURVEY OF CANADA

THE CARBONIFEROUS OF EASTERN CANADA(1)

by

P.A. HACQUEBARD

OTTAWA

1971

---

(1) Manuscript of invited lecture, for publication in Compte Rendu of 7th International Congress of Carboniferous Stratigraphy and Geology; Krefeld, Germany, August 23-28, 1971.

OPEN FILE
76
OCT 6 1971
GEOLOGICAL SURVEY,
OTTAWA

THE CARBONIFEROUS OF EASTERN CANADA

CONTENTS

CONTENTS (cont.)

THE CARBONIFEROUS OF EASTERN CANADA

P.A. Hacquebard
Geological Survey of Canada, Ottawa, Canada

ABSTRACT

The Carboniferous comprises six rock units, which in ascending order are named the Horton, Windsor, Canso, Riversdale, Cumberland and Pictou Groups. Palynostratigraphic studies indicate the presence of at least 17 miospore zones which have extended the age of the groups downward to Middle Devonian and upward to Lower Permian.

Major tectonic elements are stable platforms and a mobile region, called the Fundy eqieugeosyncline, consisting of a series of connected troughs separated by uplands. Their configuration changed with time and during upper Westphalian the entire region became a stable craton. Diagrams illustrate this tectonic development.

Sedimentation was predominantly continental, except for the Windsor Group which is mainly marine. Continental sedimentation is represented by fan-conglomerate, fluvial, lacustrine and palludal facies. The marine beds are limestone, dolomite, gypsum, anhydrite and salt. The lithology and biostratigraphy of the six groups are illustrated in four, three-dimensional diagrams, containing a large number of columnar stratigraphic sections. Based on the palyno-stratigraphic correlations of these sections, the regional development of the various facies is discussed.

Age, location, production and reserves of mineable coals are briefly mentioned. The fundamental differences that exist between platform coals and those laid down in mobile regions are illustrated with cross-sections, palyno-petrographic profiles and coal-facies diagrams of the seams of the Sydney and Pictou coalfields. Tectonism is regarded as the prime cause of the development of principally different coals.

Regional variations in the rank of coal (or dispersed coaly matter) in Upper Paleozoic surface rocks are shown in an isoreflectance map. This map indicates a broad correlation between rank and tectonic development of the region.

I INTRODUCTION AND ACKNOWLEDGMENTS

Carboniferous rocks have a widespread distribution in Eastern Canada, occupying an area of at least 300 by 500 miles and covering parts of the provinces of Newfoundland, Quebec, Prince Edward Island, Nova Scotia and New Brunswick, as well as occurring under the greater part of the Gulf of St. Lawrence. These rocks are economically significant mainly because of the presence of coal and industrial minerals such as gypsum - anhydrite, salt, barite, dolomite and limestone, and because of their potential for oil and gas.

The geological studies of the Carboniferous fall into three periods. The first comprises the pioneering work in the second half of the 19th century by Dawson (27), Logan (67), and Fletcher (33-37), who through detailed measurements of sections, collection of fossils and field mapping brought a general outline of the Carboniferous formations in the Maritime Provinces. The second period is represented principally by the detailed paleontological and stratigraphic studies of Bell (7-17), who introduced the modern stratigraphic subdivisions and made close comparisons with the Carboniferous of Europe and the United States. The third period extends from the Second World War to the present time. Through greatly expanded activities in field mapping, numerous officers of the Geological Survey of Canada provided essential information for compilations by Neal (74) and Poole (81) on the tectonic framework, by Kelley (63, 64) on new concepts of Carboniferous stratigraphy and by Howie and Cummings (58) on regional sedimentation and pre-Carboniferous basement features. During this time important contributions were made also by the staff and students of the Summer School at Crystal Cliffs in Nova Scotia, which was operated jointly by the Nova Scotia Department of Mines and the Massachusetts Institute of Technology. Most notable of this group are the publications by Murray (73), Sage (85) and Belt (18-21). During the sixties detailed sedimentological and facies studies were initiated also: on non-marine Pennsylvanian rocks of New Brunswick by van de Poll (94) and on the marine Windsor beds by Schenk (87).

The Geological Survey of Canada not only instituted increased activities in geological mapping and compilation studies, but also paid particular attention to the coal deposits by creating a Coal Research Group that was stationed in Sydney, Nova Scotia between 1949 and 1959 and since then has continued in Ottawa, Ontario. The author heads this group and under his guidance activities in coal petrology, coal sedimentation and Carboniferous palynology have been carried out. As a result the accent of this treatise is on the palyno-stratigraphy and coal deposition in the Carboniferous of Eastern Canada.

The author gratefully acknowledges the cooperation he received from Mr. M.S. Barss of the Geological Survey of Canada, who provided invaluable information on palynological zonations not previously published. Thanks are extended also to the Cartography Section of the Geological Survey for assistance rendered in the drafting of the diagrams, and to Dr. E.J.W. Irish who edited the text.

II TECTONIC AND STRATIGRAPHIC OUTLINE OF UPPER PALEOZOIC SEDIMENTATION

1. Tectonic Framework

The Carboniferous of Eastern Canada forms part of the Appalachian mountain system which is situated on the eastern side of the North American continent. This mountain system extends 3200 kilometers northeastward along the Atlantic seaboard from Alabama to Newfoundland, and thence beyond to the edge of the Continental Shelf. It possibly was once continuous with the Caledonian Mountains on the eastern side of the North Atlantic, in Ireland and Britain. In Figure 1, which shows the Paleozoic pre-drift position of North America and Europe according to Bullard *et. al.* (24), a striking alignment of the two mountain chains is apparent.

Carboniferous sedimentation was controlled by tectonism that constituted the final phase of deformation of the Appalachian geosyncline. Following the Acadian orogeny of mid-Devonian time, a stable area with a zone of steep northeasterly trending faults developed across the region, from Bay of Fundy in the southwest to White Bay in northern Newfoundland. Regional subsidence of the faulted zone caused the formation of a series of connected troughs and intermontane basins, which have been referred to collectively as the Fundy Basin, or Fundy eqieugeosyncline (64, 81). I occupies parts of the provinces of New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland, and the southern part of the Gulf of St. Lawrence.

Belt (20) has interpreted the Fundy Basin as a complex rift valley, bounded on both sides by a system of high-angle faults which were active during sedimentation. As a result, the facies changes parallel the fault trends, with the coarse facies being confined to narrow zones near the faults and the fine facies occurring in the central part of the rift valley. According to Belt (21), a similar facies pattern, tectonic framework and age of rifting exist in the Carboniferous of Northern Ireland and Scotland. He therefore contends that the Midland Valley and the Fundy Basin were once part of the same rift valley system, which existed during the Upper Paleozoic before the continents drifted apart.

Following the Acadian orogeny, Upper Devonian, Carboniferous and Lower Permian rocks were deposited in the Fundy Basin and adjoining platforms. They reached their maximum thickness and most complete stratigraphic succession in the Fundy Basin. The isopach map of Figure 2 shows that maxima in excess of 8 km occur in the Gulf of St. Lawrence near the Magdalen Islands, and in the SE part of Prince Edward Island. On the New Brunswick and Nova Scotia Platforms, however, the total sedimentary cover is considerably thinner, being less than 2 km. Figure 2 also shows the pre-Carboniferous positive areas from which much of the detritus of the predominantly non-marine formations was derived.

2. Stratigraphic Subdivisions

The six major subdivisions of the Carboniferous that were proposed originally by Bell in 1927 (9) are still in general use today. Bell called these units groups, implying a lithological connotation, although they were defined mainly by age as indicated by fossils. The names of the groups are, in ascending order: Horton, Windsor, Canso, Riversdale, Cumberland and Pictou. They were originally considered to be separated by intervals of non-deposition, and with few exceptions were thought to be bounded by disconformities or unconformities. These intervals are shown in Table I by the three vertically ruled areas. The respective ages of the groups, as determined by Bell (13), are based on plant megafossils and marine invertebrates. They range from the Tournaisian to Westphalian D.

Increased knowledge in recent years of the stratigraphy, sedimentation and particularly the palynology of the Carboniferous has led to significant changes in Bell's interpretations. Most important is the observation that the groups are essentially conformable and that existing unconformities are of limited extent, being caused by local movements only (64).

As regards their time-stratigraphic relationship, the six groups together represent a complete record without significant breaks in deposition. In the various sub-basins the same groups can include different ages, and different groups

Bell - 1927 & 1958	Barss & Hacquebard, 1971		AGE		
GROUP	GROUP	SPORE ZONE			
	Pictou	e	LOWER PERMIAN		
		d	STEPHANIAN		CARBONIFEROUS
Pictou		c	WESTPH.	D	
		b		C	
		a			
Cumberland	Cumberland	f		B	
Riversdale	Riversdale	e		A	
		d	NAMURIAN		
Canso	Canso	b\c			
Windsor	Windsor	a ↓ ?	VISEAN		
Horton	Horton	g	TOURNAISIAN		
		f			
		e			
		d			
		c	UPPER	DEVONIAN	
		b			
		a	MIDDLE		

Table I. Stratigraphic subdivisions and age of Upper Paleozoic rocks in eastern Canada.

can overlap in time and thus become partly diachronous, as indicated in the central column of Table I by the zigzag boundaries. This is an important result of the spore studies carried out by Hacquebard, Barss and Donaldson from 1957-1963, and by Barss since 1964. A total of 17 miospore zones are presently recognized; the zones not only have revealed the diachronous character of some of the groups, but also have extended their known age beyond the Carboniferous into the Devonian and Permian.

III TECTONISM, BIOSTRATIGRAPHY AND LITHOLOGY OF THE MAJOR ROCK UNITS

1. Tectonic Elements of Upper Devonian and Dinantian

A subsiding Fundy Basin, together with upland areas and bordering platforms constitute the principal tectonic elements of the Carboniferous period. Its configuration during the deposition of the Horton and Windsor Groups, comprising strata of Late Devonian and Dinantian ages, is shown in Figure 3A. Undisturbed, flat-lying Horton and Windsor rocks occur on the New Brunswick and Nova Scotia Platforms and were found also by Belt (21) on the Central Newfoundland Platform at Red Indian Lake (approximately 80 km east of the map boundary). Sediments deformed by the so-called Maritime Disturbance (81) occur only in the Fundy Basin. They have been referred to as the Prince Edward Island (P.E.I.) Mobile Belt by van de Poll (94). The rocks in the mobile belt are characterized by local unconformities, folds and high-angle faults which often mark the border between the sub-basins and upland areas (64). The latter are the Westmoreland, Caledonian, Cobequid, Antigonish and Cape Breton Highlands massifs. They provided part of the detritus of the continental Horton sediments.

2. Biostratigraphy and Lithology of the Horton Group

The biostratigraphic zonation of the non-marine Horton Group is based on spore investigations that have been carried out by Hacquebard (42), Playford (80), McGregor (70), and Barss (in preparation). This study has advanced now to the point where Barss has been able to recognize seven miospore zones. The characteristic types of his provisional zonation are shown in Table II.

Zone	Characteristic Types	Age
g	*Vallatisporites vallatus* Hacquebard; *Pustulatisporites pretiosus* Playford	TOURNAISIAN
f	*Lophozonotriletes malevkensis* (Naum.) Kedo; *Reticulatisporites fimbriatus* Winslow	
e	*Hymonozonotriletes explanatus* (Luber) Kedo	
d	*H. explanatus*; *Hystricosporites* sp.	
c	*H. lepidophytus* Kedo; *H. pusillitus* Kedo	LATE DEVONIAN
b	*Dicrospora multifurcata* Winslow; *Ancyrospora* sp.	
a	*Emphanisporites annulatus* McGregor; *Brochotriletes* sp.	MIDDLE TO EARLY DEVONIAN

Table II. Provisional miospore zonation of the Horton Group, (after M.S. Barss 1971, personal communication).

Miospore zones a, b and c are typical of the (Lower), Middle and Upper Devonian. Sediments containing these zones, therefore, can be no longer regarded as Carboniferous, but nevertheless remain included in the Horton Group because of their rock-stratigraphic relationship to this group. The remaining four zones, from d to g, signify a Tournaisian age.

The biostratigraphic zonation and lithology of eleven representative sections of the Horton Group is shown in the three-dimensional diagram of Figure 4. Three similar diagrams have been constructed for the other major rock units. In each the composite stratigraphic sections, plotted in columnar fashion, represent specific areas that are indicated in the title description. The faces of the columns show the lithology and colour of the rocks, whereas the right-hand panels indicate the local names of the rock units and the established spore zones (marked in lower case letters). Detailed literature references pertaining to the source of information for each column are given also. The four three-dimensional diagrams, therefore, provide the reader with a synthesis of available information on the lithology and stratigraphy of the Carboniferous of Eastern Canada, in an easily accessible and comprehensible manner.

The Horton Group consists of a sequence of continental sediments, with some local volcanic intrusions in the lower part and possibly some marine or brackish water deposits in the upper part. The thickness varies from 300 m on the Nova Scotia Platform to 3,550 m in the Fundy Basin. Only in column 3, representing the Moncton sub-basin, an additional 850 m of continental deposits of the Hillsborough Formation are included. Elsewhere these deposits are equated with marine limestones of the Windsor Group.

The earliest Horton rocks were laid down in isolated areas at the locations of columns 3, 4 and 6. They contain spore zones a, b and c, and their Devonian age is marked with the letter D to the left of the columns. The oldest rocks, with spore zone a, are present in column 4. Here the River John Series consists of predominantly medium-grained, red clastics of fluvial origin, which in the lower half of the section contain several interbedded volcanic flows and one lacustrine interval of dark shales and oil shales. In columns 3 and 6 mainly coarse-grained red and grey clastics of fan-conglomerate origin are represented which belong to the Memramcook and McInnis Brook Formations. Both contain different spore zones, namely b and c, but the possibility of correlating the latter with the upper part of the former should not be ruled out. The red siltstones in the upper part of the Memramcook Formation precluded a spore study of these beds.

When considering the Tournaisian part of the Horton Group, it will be noted that miospore zones d, e and f are of limited regional extent, whereas zone g has been encountered over nearly the entire region. There are several reasons for this: 1) onlap of younger strata on pre-Horton platforms and upland areas, e.g. columns 1, 2, 5, 7 etc.; 2) discontinuity of exposed sections, restricting sampling possibilities, e.g. column 3; 3) occurrence of rock types not amenable to preserving fossil spores, such as red beds and conglomerates at horizons where stratigraphically certain zones should occur, e.g. between zones b and e in column 3; 4) incompleteness of present spore study.

In comparison with the other spore zones, zone g not only has the greatest regional extent, but also occurs throughout a much thicker section of sediment, attaining a maximum thickness of about 1,500 m. In most columns this section contains three rock units, namely one unit of fine clastics lying in between two units of coarse clastics. This threefold subdivision is best exposed in Cape Breton Island at column 7, where in ascending order the rock units were named Craignish, Strathlorne and Ainslie Formations (73).

The lower part of the Craignish in column 7, and its equivalents in columns 9, 10 and 11, are developed as a typical alluvial fan-conglomerate facies, the coarse detritus of which was derived from the nearby uplands. Both laterally and vertically the conglomerate grades into finer grained fluvial sediments, most of which are red sandstone.

The red sandstone in turn is followed in column 7 by grey, fine clastics of the Strathlorne Formation. Similar deposits occur at about the same stratigraphic position throughout the Fundy Basin. They were laid down in lake, fluvial plain and swamp environments, as is attested by the occurrence of finely laminated black shale, bituminous shale, siltstone, sandstone and coal. During this time or shortly thereafter, some local marine influence also occurred, as is indicated by the presence of salt in column 3. At this same location the only oil and gas field of the Atlantic region is found also, with production from the Albert Formation which contains spore zone g.

In column 7 the grey fine clastics are succeeded by the Ainslie Formation, which consists of red and grey sandstone with interbedded siltstone, and conglomerate in the vicinity of the uplands. Similar fluvial deposits occur throughout the region in the upper part of zone g, attesting to increased epeirogenic subsidence as compared to the preceding lacustrine phase of deposition.

Thin coal seams, not exceeding 20 cm in thickness, occur at a few isolated localities in zone g, e.g. in columns 2 and 6. They probably all lie at the stratigraphic position of the Strathlorne Formation. The coal of column 2 was used for the original spore study of the Horton Group (42), and is the type locality of the genus *Vallatisporites* Hacquebard, 1957.

3. Biostratigraphy and Lithology of the Windsor Group

The biostratigraphy and lithology of the Windsor Group are shown in Figure 5. The group is thin, varying between 76 and 1,280 m in thickness. For this reason the vertical scale used in Figure 5 is twice as large as that employed in the other three-dimensional diagrams. The Windsor is unique in the Carboniferous succession in that it contains marine carbonates and evaporites within red, nonmarine sediments. A typical sequence consists of a basal limestone, overlain by thin red lutite (mudstone), followed by gypsum or anhydrite, and capped by a very thick red lutite or red shale member (10, 87).

The biostratigraphic subdivision of the Windsor Group was made by Bell in 1929 (10), mainly on the basis of brachiopods and corals. He established five subzones (referred to from A to E) and two zones, designated as Lower and Upper Windsor and marked with the letters L and U in the columns of Figure 5. Two subzones occur in L, and a maximum of three are present in U. The diagnostic fossils are shown in Table III.

Macrofauna - Bell 1958					Foraminiferal Zones Mamet 1970	Age
Age	Zones		Brachiopods & Corals			
ISEAN	Upper Windsor	E	*Martinia galataea*	*Caninia dawsoni; Chonetes politus*	17	EARLY NAMURIAN
		D		*Productus semicubiculus*	16_s	LATE VISEAN
		C		*Dibunophyllum lambii; Nodosinella priscilla*	16_i	
	Lower -	B	*Composita dawsoni*	*Diodoceras avonensis*	15	
		A		Basal limestone		

Table III. Faunal zonation of the Windsor Group.

According to Bell (16) the macrofauna indicates a Visean age, but recent studies of the microfauna by Mamet (69) show a correlation with the late Visean-earliest Namurian of Western Europe, i.e.with foraminiferal zones 15 to 17. The Visean - Namurian boundary according to these zones is marked to the left of the columns by the letter N in Figure 5.

Deposition of Windsor rocks took place in a shallow sea which inundated the area at the close of Horton sedimentation. General epeirogenic subsidence affected most of the Fundy Basin and some of the bordering platforms. According to Schenk (87), the carbonates are mainly shallow marine to supratidal; the calcium sulfate is mainly supratidal and the result of precipitation within salt flats; and the red beds are of subaerial origin.

Lower Windsor strata probably covered nearly the entire Fundy Basin and a large part of the Nova Scotia and New Brunswick Platforms as well. On the average it contains 30% evaporites, 10% limestones and dolomites, and 60% red beds (shales, marls and siltstones), although these percentages may vary considerably in different localities (84). Much of the evaporites is gypsum and anhydrite, but thick salt occurs at a number of localities, notably in column 8 where it is being mined at Pugwash. The evaporite deposits have had a very noticeable effect on the deformation of certain areas, and diapiric structures are known from several places. One of these structures, situated in the eastern part of the Cumberland sub-basin at Springhill, had a pronounced influence on the structure of the overlying coal measures, and adversely affected underground mining. During Lower Windsor time there was also some local volcanic activity, as is revealed by the occurrence of lava flows, bombs and ash beds in columns 9 and 12.

Upper Windsor strata are less extensive than those of the Lower Windsor, indicating a gradual retreat of the sea. They are notably absent from the New Brunswick Platform (columns 1 and 3 only show Lower Windsor), and in the Moncton and Cumberland sub-basins Upper Windsor is present at one location only, which is marked in column 6. The Upper Windsor contains on the average 20% evaporites, 8% limestones and dolomites, and 72% red beds (84). This represents more continental and less marine sediments than are present in the Lower Windsor. However, in the Newfoundland section plotted in column 15, the amount of clastic rocks in both Upper and Lower Windsor is even larger, indicating close proximity to the original shore line on the Newfoundland Platform.

4. Tectonic Elements of Namurian and Lower Westphalian

The tectonic elements that existed during Namurian and Early Westphalian time, when rocks of the Canso, Riversdale and Cumberland Groups were deposited, are shown in Figure 3B. In contrast to the Late Devonian and Dinantian, when the so-called Prince Edward Island Mobile Belt occupied the entire Fundy Basin, only a part remained active during this time. Van de Poll (94) has named this part the Cumberland Mobile Zone, and the remaining stable area the Prince Edward Island Platform.

As a result of this new configuration the area of relatively undisturbed, flat-lying cratonic sediments was greatly increased, and only a narrow zone with folded rocks now forms the remaining active part of the Fundy Basin. It was in this zone during the Namurian and Westphalian A and B that the greatest accumulation of continental sediments took place.

5. Biostratigraphy and Lithology of the Canso, Riversdale and Cumberland Groups.

The palyno-stratigraphic zonation of the Canso, Riversdale and Cumberland Groups was made by Barss and reported on by Belt (20). Additional spore information concerning the lower Canso Group was contributed by Neves and Belt (75), and concerning the Cumberland Group by Hacquebard and Donaldson (45).

Barss originally recognized six miospore zones, which he designated with the letters a to f. However, as a result of a study of a larger number of samples he concluded that zones b and c can no longer be separately identified in most cases. Therefore, they have been combined and in order not to confuse the previously published spore zonation, no new order is introduced, but the designation c/b is used. The diagnostic types of the miospore zones are shown in Table IV.

As is indicated in Table IV, the lower three zones are Namurian and the upper three zones are Westphalian A and B in age. Their stratigraphic relationship to the three groups can be seen in the right hand column. It shows that miospore zones a, e, f and g are each restricted to one group only: a to the Canso (although it occurs also in the underlying Windsor Group), e to the Riversdale and f and g to the Cumberland. Zones c/b and d, however, are found in rocks that have been assigned to both the Canso and Riversdale Groups. This shows that the groups are essentially lithostratigraphic and not biostratigraphic units.

Zone	Characteristic Types	Group	Age
g	A transition zone, containing elements of zone f, but with first appearance of *Vestispora cancellata* (Dyb. & Jach.) Wils. & Venk.	Cumberland	WESTPH. B
f	Acme of *Lycospora* spp.; *Savitrisporites nux* (Butt. & Will.) Sullivan; *Densosporites* spp.		
e	*Laevigatosporites* spp.; first appearance of *Triquitrites* spp.; *Reticulatisporites polygonalis* (Ibr) Loose; *Savitrisporites nux*.	Riversdale ↓	WESTPH. A
d	*Potonieisporites elegans* (Wils. & Kos.) Wils. & Venk.; *Knoxisporites seniradiatus* Neves; rare *Laevigatosporites* spp.		NAMURIAN
c/b	*Vallatisporites ciliaris* (Luber) Sullivan; *Knoxisporites stephanephorus* Love; *Grandispora spinosa* Hoff.		
a	*Rugospora* spp.	↑ Canso	

Table IV. Provisional miospore zonation of the Canso, Riversdale and Cumberland Groups (after M.S. Barss in Belt (20), and personal communication in 1971).

The biostratigraphy and lithology of the Canso, Riversdale and Cumberland Groups are shown in Figure 6. The greatest development of the three groups combined is shown in column 3, representing the Cumberland sub-basin. There, a total thickness of 5,200 m of entirely non-marine strata is represented. In contrast, only about 200 m are present at some platform localities, e.g. columns 5 and 8.

As can be seen from the prevailing lithological symbols in the columns, the sediments consist almost entirely of fine clastics and coal. Fluvial, lacustrine and palludal environments existed during this period. Detailed sedimentological and paleogeographic studies by Belt (20), incorporating the spore zonation of Barss, have revealed the presence of several lake systems during the time of miospore zones a to e. The lake deposits consist of dark to medium grey laminated shales. They developed farthest from the source areas and pass laterally into fluvial deposits, which are represented by red shale, red lutite and fine grained sandstone.

During miospore zones a and c/b the lake system reached its greatest extent as is indicated by the occurrence of grey shale in columns 1, 6, 7, 9, 11, 12 and 14. Subsequently this lake contracted considerably and during zone d it occurred only in the region of columns 7 and 9. Finally, at the time of zone e, a last vestige of lacustrine deposition took place at two widely separated areas, namely at columns 1 and 10. Palludal conditions leading to the formation of coal were restricted to zones e and f, or to Westphalian A and B. They include the coal deposits of the Riversdale and Cumberland Groups that have been mined at the locations of columns 3, 9 and 10. The greatest succession of coal measures is present in zone f of column 3. It represents the famous Joggins shore section that was first described by Sir William Logan in 1845 (67). It is 1,500 m thick and contains no less than 65 separate coal horizons, but only a few reached a mineable thickness, not exceeding 1 m. The detailed stratigraphic succession and the characteristically high content of *Lycospora* of these coals have been illustrated by Hacquebard and Donaldson (45).

In view of their time-transgressive aspect, Belt (18, 19) has proposed that the four Upper Carboniferous groups of Bell be replaced by two units which are strictly lithogenetic in origin. These units he named Mabou Group and "Coarse Fluvial Facies". In the Mabou Group are included the fine-clastic, lutaceous strata that formerly had been assigned to the Upper Windsor, Canso and Riversdale Groups. The remaining non-lutaceous and predominantly coarse-clastic rocks are collectively referred to as "Coarse Fluvial Facies". They are in part laterally equivalent to the Mabou Group and in part equal to the overlying Cumberland and Pictou Groups.

The boundaries of the Mabou Group are marked with the letter M to the right of the columns in Figure 6. The group is time-transgressive, including miospore zones a, c/b, d and part of e in columns 9 (type section) and 1, but only a and c/b in columns 2, 3 and 4.

When first proposed in 1962, Belt's Mabou Group appeared to offer distinct advantages over the original groups of Bell because it emphasized lithology and clearly revealed for the first time the diachronous nature of these groups. His "Coarse Fluvial Facies", however, was generally regarded as an oversimplification which would result in a loss of detailed stratigraphic and lithological information. More recent studies by van de Poll (94), moreover, have clearly indicated that the "Coarse Fluvial Facies" cannot be regarded as a valid litho-stratigraphic unit because it represents a highly variable, multi-provenant sequence. Because of this, and in accordance with Kelley's proposal of 1967 (63) to retain the original group names of Bell (but with extended time boundaries and emphasis on litho-stratigraphy), the author considers continued usage of the term Mabou Group superfluous. The miospore zonation has shown that at present this group represents little more than an upward stratigraphic extension of the Canso Group. Since the latter name has precedence over the former, continued use of the term Canso Group is advocated.

6. Tectonic Elements of Upper Westphalian to Lower Permian

Figure 3C shows the tectonic elements of Late Westphalian to Early Permian time, when rocks of the Pictou Group were laid down. As can be seen the entire Fundy Basin was a stable craton since the Cumberland Mobile Zone had ceased to be active and had become another platform region. Only two small areas with folded Pictou rocks (shown in heavy dots) point to the last manifestation of tectonic activity of the region during Paleozoic time, except for general epeirogenic subsidence. The latter was most pronounced in the centre of the Fundy Basin, where the greatest thickness of Pictou strata accumulated, but also affected the sub-basins, most notably the Sydney coalfield. Flysch-like, nearly flat-lying deposits were laid down throughout the Atlantic region and rest with marked angular unconformity on older strata almost everywhere (64).

7. Biostratigraphy and Lithology of the Pictou Group

The palyno-stratigraphic zonation of the Pictou Group was made by Barss and Hacquebard (6). They recognized five miospore zones and named these after the most diagnostic genus present. The zones are shown in Table V, but contrary to the previous tables the characteristic types that make up the spore assemblage of each zone are not listed. These can be found in Figure 2 of publication (6). The table also shows that the lower three spore zones coincide with three floral zones established by Bell (11) in the Sydney coalfield. These floral zones have been correlated with the Westphalian C and D of Europe, and this correlation is followed also for the corresponding miospore zones a, b and c. It is realized that on the basis of a comparison of miospores only a somewhat different age correlation may result, particularly as regards the boundary between Westphalian C and D (44).

Due to a scarcity of plant megafossils, Bell was unable to assign an age younger than Westphalian D to any rocks belonging to the Pictou Group. However, from the presence of the *Potonieisporites* and *Vittatina* assemblages, which occur in previously undated rocks, we now know that the Pictou Group extends through the Stephanian into the Early Permian.

The biostratigraphy and lithology of the Pictou Group are shown in Figure 7. The group varies in thickness from less than 100 m in column 3 to about 2,400 m in column 13, which represents a subsurface section of eastern Prince Edward Island. The maximum thickness of 2,700 m is reached in the structural graben of the Pictou coalfield, illustrated in column 12.

The continental Pictou beds are developed in two distinctly different facies, namely a grey coal-bearing series and a predominantly red, mainly non-coal-bearing

Spore Zones Barss & Hacquebard, 1967	Floral Zones Bell, 1938	Age	
e *Vittatina*	(no plant megafossils)	LOWER PERMIAN	
d *Potonieisporites*		STEPHANIAN	
c *Thymospora*	*Ptychocarpus unitus*	WESTPH.	D
b *Torispora*	*Linopteris obliqua*		C
a *Vestispora*	*Lonchopteris*		

Table V. Miospore zonation and floral zones of the Pictou Group.

sequence. The grey series, which was referred to by Bell (13) as the Minas Basin facies, occurs in columns 3, 7, 8, 12, 14, 15, 17 and 18. Mostly fine grained, grey sediments that were deposited in lacustrine, palludal and flood-plain environments are represented. Most of the economically important coal measures of Eastern Canada belong to the grey Pictou facies, specifically those occurring in columns 12 (Pictou), 14 (Mabou), 15 (Inverness) and 18 (Sydney). They contain spore zones a, b or c, and are of Westphalian C and D age.

The red Pictou facies, called Cumberland Basin facies by Bell (13), is mainly of fluvial and fluvial-lacustrine origin and contains, in places, a few thin coal seams, e.g. in columns 2, 5, 6 and 10. This facies occurs over the greater part of the Fundy Basin and New Brunswick Platform, and according to van de Poll (94) comprises three mega-cyclothems. Each mega-cyclothem is at least 100 m thick and consists of a series of relatively coarse grained, grey clastics, overlain by a sequence of finer grained red beds. Coal or dark grey siltstone is found at the junction between the grey and red-bed sequence of each cyclothem. The three mega-cyclothems include and partly coincide with miospore zones a, b and c+d, but van de Poll states that at present there is insufficient evidence to determine conclusively if they are a time-bounded or a time-transgressive feature.

In the central part of the Fundy Basin the deposition of red beds without coal or appreciable grey interbeds continued during the Stephanian and Early Permian, as can be seen in columns 9 and 13. Rocks containing the *Vittatina* assemblage, denoting a Permian age, were found only in the Hillsborough Bay area of eastern Prince Edward Island (zone e in column 13).

IV. COAL, ITS RESOURCES, FORMATION AND RANK

1. Distribution, Production and Coal Reserves.

A brief review of the geology, structure, coal-bearing sequence, number and development of mineable seams, type and rank of coal, production, reserves and mining characteristics of the coalfields of Eastern Canada was given by Hacquebard in "Geology and Economic Minerals of Canada" (43). A few pertinent details of that article are presented here.

Although coal is present in the Lower Carboniferous, the productive coal measures of Eastern Canada are confined to the Upper Carboniferous. As can be seen from Figure 8, mineable coal is present in the Riversdale, Cumberland and Pictou Groups.

The Riversdale coals have been mined on the west side of Cape Breton Island, in the Port Hood and St. Rose-Chimney Corner coalfields. Production in these fields hasbeen small and reserves are limited. The Cumberland coals have been mined at Joggins - River Hebert and Springhill, and the total production of these areas has amounted to 42 million tons. The Pictou Group coals have provided the largest tonnage, totalling 438 million tons during a 180 year period from 1785 to 1965. The coalfields of Minto, Pictou, Mabou, Inverness and Sydney belong to the Pictou Group.

It is apparent from the diagram that the largest production and greatest reserves are in the Sydney coalfield. 72% of the total production of the entire region has come from this field, and the indicated reserves amount to 556 million tons.

At present large scale operations are carried out only in the Minto and Sydney coalfields, and in the Sydney field extraction is entirely from the submarine area. In the other coalfields, all the larger mines have been closed and only a few minor operations are now in progress. The coal industry of the region has declined steadily during the past 20 years, from about 7,500,000 tons in 1950 to about 3,500,000 tons in 1969.

2. Coal Formation on Platforms and in Tectonically Active Regions

The formation of coal requires a particular type of depositional environment, which is controlled by the rate of subsidence, the compaction, the hydraulic conditions of the basin, the kind of vegetation and its mode of preservation (47). These factors are all interrelated, but the prime force that causes major differences in the environment is tectonism. Coal present on stable platforms was subjected to different conditions than coal formed in active mobile belts. The main differences reflected in the type of coal and character of the enclosing sediments are as follows:

The platform coals are distinctly banded, heterogeneous and of autochthonous origin. They are associated with fluvial and fluviolacustrine sediments typical of a flood-plain environment. On the other hand, the coals occurring in mobile regions, are finely laminated, more homogeneous and of hypautochthonous origin. They are accompanied by fine-grained clastics typical of a limnic environment, which grade into coarser rocks towards the periphery of the basin.

A. Seam development, palyno-petrography and facies changes in platform coals.

Platform coals in Eastern Canada are represented by the coals of the Pictou Group, with the exception of those of the Pictou coalfield. The platform coals of the Minto, Mabou, Inverness and Sydney coalfields all have essentially the same characteristics, and those of the Sydney field have been chosen as an example.

Figure 9a shows cross-sections through 5 major seams of the Sydney coalfield. The observation points for these sections are marked along the section lines in the map at the top of the diagram. The five seams illustrated encompass a stratigraphic interval of 158 m. In the cross-sections, black represents coal, and white the rock partings that occur in association with it. The characteristic features of the seams, typical of a flood-plain environment of deposition, are as follows(47):

(1) The seams rarely exceed 2 m in thickness. They are of great lateral continuity and maintain about the same amount of total coal, notwithstanding the introduction of rock partings. This last feature is well illustrated in the Boutilier and Emery seams.

(2) The seams show splitting and digitation of the coal by rock partings that are the result of interaction between fluviatile and palludal environments of deposition.

(3) The seams terminate by splitting and gradual pinching out of individual coal benches, not by a lateral transition of coal into shale.

Figure 9b shows the palyno-petrographic profile of the Harbour seam. It is typical of an autochthonous coal that was formed from an *in-situ* vegetation. This vegetation and its mode of preservation were greatly affected by changes in the groundwater table. Increases in the level of the groundwater in the peat bog caused the formation of dull bands, several of which can be traced over long distances. In the seam section illustrated, ten durite or clarodurite bands are present, seven of which show up in the percentage diagram (e.g. intervals 3, 4, etc.). Also, there are significant changes in overall composition between roof and pavement. The upper 1/3 of the seam (with intervals 7, 8 and 9) is considerably higher in duroclarite and clarodurite than the lower 2/3.

These changes in petrographic composition are accompanied by changes in the spore distribution. The spore histogram at the right of Figure 9b indicates that the lower 2/3 of the seam is high in *Lycospora*, while the upper 1/3 is characterized by a high percentage of *Punctatosporites*. This denotes a change in vegetation from arborescent to herbaceous during the life of the seam. Such changes in vegetation are typical in peat bogs that are formed in a flood-plain environment on a stable platform. They were noted also in the other platform coals of the Pictou Group, as was shown by Hacquebard and Barss (48) for the Minto seam.

The vertical changes in petrographic composition can be traced also laterally, and from this, interpretations of coal facies can be made. For the Sydney coalfield this has been done by Hacquebard and Donaldson (47), who recognized four main facies: forest-terrestrial moor (Ft M), forest-moor (FM), reed-moor (RM) and open moor (OM). The diagnostic petrographic composition of these facies is indicated in the two adjoining ternary diagrams in the upper right hand corner of Figure 10. The assignment of the different coal types (fusito-clarite, vitro-clarite, etc.) to the various facies is based on studies by von Karmasin (60), Teichmüller (92), and Teichmüller & Thomson (93).

The facies changes present in the three seams illustrated in Figure 10 can be described as follows:

The Harbour seam has two main phases of development. The lower phase consists predominantly of the FM facies, which near the middle is interrupted by the OM facies. The upper phase has a preponderance of RM facies. These facies interpretations are in accord with the results of the palynological study previously described. They indicate a change from an arborescent to a herbaceous vegetation around the 2/3 level of the seam section.

The Backpit seam is characterized by OM facies in the upper and lower parts, and by a dominance of the FtM facies in the middle. Only in this seam has an appreciable development of the forest-terrestrial-moor facies been observed.

The Phalen seam is dominated by the FM facies. Only the bottom bench is represented by a RM facies, and OM conditions happened only once during the life of this seam.

From Figure 10 it is apparent that each seam has a particular facies development differing from that of another seam. Such facies changes are typical in platform coals and were also observed by Hacquebard and Barss (48) in the Minto coal seam of New Brunswick.

B. Seam development and palyno-petrography of coals formed in a mobile region.

The Pictou coalfield is an excellent example of coal deposition in a tectonically active region. Coal formation took place in a narrow, intermontane lake basin bounded by faults of large displacement, making it a graben structure.

In this basin the fine clastic rocks with finely dispersed organic debris, such as the black shales, occupy a central position. They are flanked by areas of grey shale, which in turn are bordered by more sandy sediments. The coal seams reveal a similar picture of clean low-ash coal in the centre and coarse high-ash coal at the periphery. The cross-sections of the three seams shown in Figure 11a reveal this clearly. They are plotted in the same manner as was done for the Sydney coalfield, and the observation points are marked in the map at the top of the diagram. The three seams illustrated are from the Albion District of the Pictou coalfield and encompass a stratigraphic interval of 71 m. The characteristic features of the seams, typical of a limnic environment of deposition, are as follows (47):

(1) The seams are of great thickness but of limited lateral extent, reaching a maximum of 13.4 m in the Foord seam.

(2) The area of best coal is in the centre of the basin and in general increases in size from the older to the younger seams. This feature is more clearly revealed in Plate 2 of publication (47).

(3) The seams terminate by lateral transition of coal into shale through zones of shaly coal and coaly shale. This lithification of "Versteinerung" is in

marked contrast to the termination by splitting and digitation as represented by the platform coals previously discussed.

Figure 11b shows a palyno-petrographic profile that is typical of the seams of the Pictou coalfield. The coal is finely banded and varies but little in petrographic composition between roof and pavement. It consists essentially of a monotonous alternation between clarite and duroclarite bands, which are separated by thin vitrite layers. Clarodurite and durite are present in minor amounts only and bands of carbargilite occur at regular intervals throughout the seam section. The percentage diagram shows that the relative amounts of the microlithotypes remain remarkably constant throughout subdivisions A, B, C and D; only E differs in that it contains more carbargilite.

The spore distribution, plotted on the right side of Figure 11b, shows an equally constant pattern, pointing to the fact that throughout the life of the seam the vegetation remained unchanged.

Coals of limnic origin were likely not derived from forested peat bogs, but may be the result of herbaceous growth along the margin of shallow lakes. Due to an inflow of streams from bordering uplands the decayed vegetal material became thoroughly stirred, transported within the lake area and mixed with inorganic matter. This resulted in the formation of hypautochthonous coal of uniform composition, which is typical of the Pictou coalfield.

Similar coals, though different in overall petrographic composition, occur in the other coalfields of the Cumberland Mobile Zone (46).

3. Regional Changes in Coal Rank

The rank of the productive coals of Eastern Canada is entirely high volatile bituminous, with the exception of those from the Pictou field which in part are medium volatile coals.

Until recently, a study of regional changes in coal metamorphism was difficult to make because of the isolated locations of coal deposits with known rank.

However, by using the vitrinite reflectance technique a large number of new rank data became available from areas containing only minor coal horizons, or possessing disseminated carbonaceous inclusions. The map of Figure 12 is based on 178 samples, and since regions with equal reflectance have been outlined it is called an isoreflectance map. The rank variations are shown in V-types, and the corresponding percentages of fixed carbon are indicated also in the legend. The samples, which are from surface or near surface exposures, range in age from Upper Devonian to Lower Permian. The main features of the isoreflectance map are as follows (49):

(1) The rank variations are not randomly distributed, but show a pattern that appears to be related to the tectonic framework of the Appalachian region. The higher-rank coaly material occurs mainly in the mobile belt, whereas the lower rank material is present on the platforms. The SE part of the New Brunswick Platform, however, forms a notable exception. A greater thickness of original overburden in the tectonically more active regions is seen as the cause for the higher rank of the coaly matter. This also includes SE New Brunswick, where studies by van de Poll (1970) have shown the removal of a considerable thickness of younger strata.

(2) There is no relationship between the rank of the surface sediments and their age. The Devonian coals of eastern Gaspé at location A have the same low rank (V5) as the Stephanian coals of the Shediac area in eastern New Brunswick (20 miles south of borehole location No. 3). The coalification in the entire region is essentially post-deformational, being caused by the maximum depth of burial that existed after folding (49).

(3) The known oil and gas occurrences of the Atlantic region coincide with the areas of lowest rank. These occurrences are marked A to E on the map. They are confined to areas possessing a rank of V5, V6 or V7, which according to the carbon-ratio theory denotes a favourable rank for the preservation of oil and gas. The region with V8 is regarded as the boundary because its rank

is generally considered as the metamorphic deadline for the occurrence of hydrocarbons, being equal to about 65% fixed carbon.

V BIBLIOGRAPHY

1. Literature Cited in Text and with Reference to Stratigraphic Columns of Figures 4-7.

1. Alcock, F.J. 1935

Geology of Chaleur Bay region; Geol. Surv. Canada, Mem. 183.

2. Baird, D.M. 1959

Geology of Sandy Lake (west half), Newfoundland; Geol. Surv. Canada, Map 47-1959 (with marginal notes).

3. ——————, 1966

Carboniferous rocks of the Conche-Groais Island area, Newfoundland; Canadian Jr. Earth Sci. V.3, pp. 247-257.

4. —————— and Cote, P.R. 1964

Lower Carboniferous sedimentary rocks in S.W. Newfoundland and their relations to similar strata in western Cape Breton Island; Canadian Inst. Min. Met. Trans., V.57, no. 625, pp. 509-520.

5. Barss, M.S., Hacquebard, P.A. and Howie, R.D. 1963

Palynology and stratigraphy of some Upper Pennsylvanian and Permian rocks of the Maritime Provinces; Geol. Surv. Canada, Paper 63-3.

6. —————— and Hacquebard, P.A. 1967

Age and the stratigraphy of the Pictou Group in the Maritime Provinces as revealed by fossil spores; Geol. Assoc. Canada, Spec. Paper no. 4, pp. 267-282.

7. Bell, W.A. 1914

Joggins Carboniferous section of Nova Scotia; Geol. Surv. Canada, Sum. Rept. 1912, pp. 360-371.

8. ——————, 1926

Carboniferous Formations of Northumberland Strait, Nova Scotia; Geol. Surv. Canada, Sum. Rept. 1924, Pt. C, pp. 142-180.

9. ——————, 1927

Outline of Carboniferous stratigraphy and geologic history of the Maritime Provinces of Canada; Trans. Roy. Soc. Can., Sect. IV, vol. 31, pp. 75-108.

10. ——————, 1929

Horton-Windsor district, Nova Scotia; Geol. Surv. Canada, Mem. 155.

11. ——————, 1938

Fossil flora of Sydney coalfield, Nova Scotia; Geol. Surv. Canada, Mem. 215.

12. ——————, 1940

The Pictou coalfield, Nova Scotia; Geol. Surv. Canada, Mem. 255.

13. ——————, 1944

Carboniferous rocks and fossil floras of northern Nova Scotia; Geol. Surv. Canada, Mem. 238.

14. ——————, 1948

Early Carboniferous strata of St. Georges Bay area, Newfoundland; Geol. Surv. Canada, Bull. 10.

15. ——————, 1948

Magdalen Islands, Quebec. Geol. Surv. Canada, Unpubl. Rept. no. 21-B-18.

16. ——————, 1958

Possibilities for occurrence of petroleum reservoirs in Nova Scotia; N.S. Dept. Mines, Halifax.

17. ——————, 1960

Mississippian Horton Group of Type Windsor - Horton district, Nova Scotia; Geol. Surv. Canada, Mem. 314.

18. Belt, E.S. 1962

Stratigraphy and sedimentology of the Mabou Group (Middle Carboniferous), Nova Scotia, Canada; unpubl. Ph.D. thesis, Yale Univ., New Haven, Conn.

19. ————————, 1964

Revision of Nova Scotia middle Carboniferous units; Am. Journ. Sci., V. 262, pp. 653-673.

20. ————————, 1965

Stratigraphy and paleography of Mabou Group and related Middle Carboniferous facies; Geol. Soc. America, Bull. V76, no. 7, pp. 777-802.

21. ————————, 1969

Newfoundland Carboniferous stratigraphy and its relation to the Maritimes and Ireland; Am. Ass. Petr. Geol., Mem. 12 (North Atlantic Geology and Continental Drift), pp. 734-753.

22. Benson, D.G. 1967

Geology of Hopewell map-area, Nova Scotia; Geol. Surv. Canada, Mem. 343.

23. ————————, 1970

Notes to accompany geological maps of Antigonish and Cape George map-areas, Nova Scotia; Geol. Surv. Canada, Paper 70-8.

24. Bullard, E., Everett, J.E., and Smith, A.G. 1965

The fit of the continents around the Atlantic, in A symposium on continental drift: Royal Soc. Canada Philos. Trans. 1088, V. 258A, pp. 41-51.

25. Carr, P.A. 1968

Stratigraphy and spore assemblages, Moncton map-area, New Brunswick; Geol. Surv. Canada, Paper 67-29.

26. Copeland, M.J. 1959

Coalfields, West Half Cumberland County, Nova Scotia; Geol. Surv. Canada, Mem. 298.

27. Dawson, J.W. 1868

Acadian Geology (2nd ed.), London, Macmillan and Co.

28. Douglas, G.V. 1944

Mabou coal area; N.S. Dept. Mines, Ann. Rept., pp. 124-131.

29. ——————, 1945

The Port Hood coal area; N.S. Dept. Mines, Ann. Rept., pp. 247-270.

30. —————— and Goodman, N.R. 1941

Chimney Corner coalfield; N.S. Dept. Mines, Ann. Rept., pp. 68-81.

31. Evans, R. 1967

The structure of the Mississippian evaporite deposit at Pugwash, Cumberland County, Nova Scotia; Ec. Geol. V. 62, no. 2, pp. 262-273.

32. Ferguson, S.A. 1946

Strait of Canso map-area, Nova Scotia; Geol. Surv. Canada, Prelim. Paper 46-12.

33. Fletcher, H. 1874

Twenty stratigraphic sections measured along the cliffs in Sydney coalfield, Nova Scotia; Geol. Surv. Canada, Ottawa Files, Notebook 1533.

34. ——————, 1892

Report on geological surveys and explorations in the counties of Pictou and Colchester, Nova Scotia; Geol. Surv. Canada, Ann. Rept. 1889-91, V. 5 (II), pt. P.

35. ——————, 1903

Pictou Sheet, Nova Scotia; Geol. Surv. Canada, map 609.

36. ——————, 1906

Section of rocks from Shulie to Spicer Cove, Cumberland County, Nova Scotia; Proc. and Trans., Nova Scotia Inst. Sci., Vol. 11, pp. 417-550.

37. ————— and Faribault, B.A. 1890

Kennetcook Sheet, Nova Scotia; Geol. Surv. Canada, map. 878.

38. Greiner, H.R. 1962

Facies and sedimentary environments of Albert shale, New Brunswick; Am. Ass. Petr. Geol., Bull., V. 46, no. 2, pp. 219-234.

39. Gussow, W.C. 1953

Carboniferous stratigraphy and structural geology of New Brunswick, Canada; Am. Ass. Petr. Geol., Bull., V.37, no. 7, pp. 1713-1816.

40. Hacquebard, P.A. 1951

The correlation, by petrographic analyses, of No. 5 seam in the St. Rose and Chimney Corner coalfields, Nova Scotia; Geol. Surv. Canada, Bull. 19.

41. —————, 1956

Palynological studies of some Upper and Lower Carboniferous strata in Nova Scotia. - Part I: Mabou coal area; Third Conf. Origin & Const. Coal, Crystal Cliffs, 1956, N.S. Dept. Mines & N.S. Research Foundation, Halifax; pp. 227-253.

42. —————, 1957

Plant spores in coal from the Horton Group (Mississippian) of Nova Scotia; Micropaleont., vol. 3, no. 4, pp. 301-324.

43. —————, 1970

"Coal" in southeastern Canada, in Ch. VII of Geology and Economic Minerals of Canada; Geol. Surv. Canada, Ec. Geol. 1, pp. 356-364.

44. —————, Barss, M.S. and Donaldson, J.R. 1960

Distribution and stratigraphic significance of small spore genera in the Upper Carboniferous of the Maritime Provinces of Canada; 4th Carboniferous Congress, Heerlen, 1958, Comptes Rendus, V. I, pp. 237-245.

45. —————, and Donaldson, J.R. 1964

Stratigraphy and palynology of the Upper Carboniferous coal measures in the Cumberland Basin of Nova Scotia, Canada; 5th Carboniferous Congress, Paris, 1963, V. III, pp. 1157-1169.

46. ————————, Birmingham, T.F. and Donaldson, J.R. 1967

Petrography of Canadian coals in relation to environment of deposition; Symposium on Sci. and Techn. of Coal, Ottawa, 1967, published by Mines Branch, Department of Energy, Mines and Resources, Ottawa, Canada, pp. 84-97.

47. ————————, and Donaldson, J.R. 1969

Carboniferous coal deposition associated with flood-plain and limnic environments in Nova Scotia; Geol. Soc. Am., Spec. Paper no. 114, pp. 143-191.

48. ————————, and Barss, M.S. 1970

Paleogeography and facies aspects of the Minto coal seam, New Brunswick, Canada; 6th Carboniferous Congress, Sheffield, 1967, V. III, pp. 861-872.

49. ————————, and Donaldson, J.R. 1970

Coal metamorphism and hydrocarbon potential in the Upper Paleozoic of the Atlantic Provinces, Canada; Canadian Jr. Earth Sci., V. 7, pp. 1139-1163.

50. Haites, T.B. 1952

Some geological aspects of the Inverness County coalfields in comparison with those of the Sydney coalfield; Second Conf. Origin & Const. Coal, Crystal Cliffs, 1952, N.S. Dept. Mines & N.S. Research Foundation, Halifax; pp. 112-135.

51. ————————, 1956

Some geological aspects of the Pictou coalfield with reference to their influence on mining operations; Third Conf. Origin & Const. Coal, Crystal Cliffs, 1956, N.S. Dept. Mines & N.S. Research Foundation, Halifax; pp. 39-74.

52. Hamilton, J.B. 1960

Chipman - Harcourt area, New Brunswick; Mines Branch, Fredericton; Rept. P.M. 60-1.

53. ————————, 1962

Correlation of the Pennsylvanian rocks in the western part of the Central Pennsylvanian basin of New Brunswick by means of fossil spores; Unpubl. M.Sc. thesis, Univ. of New Brunswick, Fredericton, N.B.

54. ————————, 1965

Limestone in New Brunswick; Dept. Lands & Mines, Fredericton; Min. Res. Rept., No. 2.

55. ————————, and Barnette, D.E. 1970

Gypsum in New Brunswick; Dept. Nat. Res. Fredericton; Rept. of Invest., No. 10.

56. Hayes, A.O., and Bell, W.A. 1923

The southern part of the Sydney coalfield, Nova Scotia; Geol. Surv. Canada, Mem. 133.

57. Hayes, A.O. and Johnson, H. 1938

Geology of the Bay St. George Carboniferous area, Newfoundland; Nfld. Geol. Surv., Bull. 12.

58. Howie, R.D. and Cumming, L.M. 1963

Basement features of the Canadian Appalachians; Geol. Surv. Canada, Bull. 89, 18 pp.

59. Island Development Co. 1945

Hillsborough No. 1 well, located in Hillsborough Bay, 7250 feet south, 51° west of Governor Island, Charlottetown, P.E.I.; Log on file at Geol. Surv. Canada, Ottawa.

60. Karmasin, K. von, 1952

Deutung des Fazies Wechsel in den Flözen Erda und Ägiz auf Grund mikropetrographischer Schlitzproben-untersuchungen; Bergbau Archiv 13, Heft 1-2, pp. 74-100.

61. Keating, B.J. 1950

Mabou coal area, Inverness County, Nova Scotia; N.S. Research Foundation files (not published).

62. Kelley, D.G. 1967

Baddeck and Whycocomagh map-areas, Nova Scotia; Geol. Surv. Canada, Mem. 351.

63. ————, 1967

Some aspects of Carboniferous stratigraphy and depositional history in the Atlantic Provinces; Geol. Assoc. Canada, Spec. Paper No. 4, pp. 213-228.

64. ————, 1970

"Carboniferous and Permian" in southeastern Canada, <u>in</u> Ch. VI of Geology and Economic Minerals of Canada; Geol. Surv. Canada, Ec. Geol. 1, pp. 284-296.

65. ————, and Mackasey, W.O. 1965

Basal Mississippian volcanic rocks in Cape Breton Island, Nova Scotia; Geol. Surv. Canada, Paper 64-34.

66. Lockhart, J.G. and Sidwell, K.O.J. 1950

Coal deposits of New Brunswick; N.B. Development Board, Fredericton, N.B.

67. Logan, W.E. 1845

A section of the Nova Scotia coal measures as developed at the Joggins, on the Bay of Fundy etc.; Geol. Surv. Canada, Rept. Prog. 1843, Appendix, pp. 92-156.

68. Mamet, B.L. 1968

Sur une microfaune du Viséen supérieur de Terre-Neuve; Naturaliste Can., V. 95, pp. 1357-1371.

69. ————, 1970

Carbonate microfacies of the Windsor Group (Carboniferous), Nova Scotia and New Brunswick; Geol. Surv. Canada, Paper 70-21.

70. McGregor, D.C. 1971

Hymonozonotriletes lepidophytus Kedo and associated spores from the Devonian of Canada, <u>in</u> Colloque sur la Stratigraphie carbonifère; Congrès et Colloques, Univ. Liège, V. 55, pp. 315-326.

71. Moore, P.D. 1932

Report on the Scotsburn anticline; N.S. Dept. Mines, Ann. Rept. 1931, pt. 2, pp. 35-42 and log of Scotsburn No. 1 well.

72. Muller, J.E. 1951

Geology and coal deposits of the Minto and Chipman map-areas, New Brunswick; Geol. Surv. Canada, Mem. 260.

73. Murray, B.C. 1960

Stratigraphy of the Horton Group in parts of Nova Scotia; N.S. Research Foundation, Halifax, N.S.

74. Neale, E.R.W., Béland, J., Potter, R.R. and Poole, W.H. 1961

A preliminary tectonic map of the Canadian Appalachian Region based on age of folding; Canadian Inst. Mining & Metall., Bull. V. 54, pp. 687-694.

75. Neves, R. and Belt, E.S. 1970

Some observations on Namurian and Viséan spores from Nova Scotia, Britain and Northern Spain; 6th Carboniferous Congress, Sheffield 1967, Comptes Rendus, V. III, pp. 1233-1242.

76. Norman, G.W.H. 1932

Stratigraphy of the Stony Creek oil and gas field, New Brunswick; Geol. Surv. Canada, Econ. Geol. Ser. 9, p. 168.

77. ————————, 1935

Lake Ainslie map-area, Nova Scotia; Geol. Surv. Canada, Mem. 177

78. ————————, 1941

Moncton sheet, New Brunswick; Geol. Surv. Canada, map 646A (with marginal notes).

79. Phillips, W.E.A., Kennedy, M.J., and Dunlop, G.M. 1969

Geologic comparison of western Ireland and northeastern Newfoundland; Am. Ass. Petr. Geol., Mem 12, pp. 194-211.

80. Playford, G. 1963

Miospores from the Mississippian Horton Group, Eastern Canada; Geol. Surv. Canada, Bull. 107, 47 p.

81. Poole, W.H. 1967

Tectonic evolution of Appalachian Region of Canada; Geol. Assoc. Canada, Spec. Paper no. 4, pp. 9-51.

82. Prince Edward Island Government 1909

No. 2 well, located 2 1/2 mi. N.E. of Earnscliff, Queens County, P.E.I.; Log on file at Geol. Surv. Canada, Ottawa.

83. Riley, G.C. 1962

Stephenville map-area; Geol. Surv. Canada, Mem. 323.

84. Roliff, W.A. 1962

The Maritimes Carboniferous Basin of Eastern Canada; Geol. Assoc. Canada, V. 14, pp. 21-41.

85. Sage, N.M. 1954

The stratigraphy of the Windsor Group in the Antigonish and Mahone Bay - St. Margaret Bay areas, Nova Scotia; N.S. Dept. Mines, Mem. 3.

86. Sanschagrin, R. 1964

Magdalen Islands; Dept. Nat. Res. Quebec, Geol. Rept. 106.

87. Schenk, P.E. 1969

Carbonate - sulfate - redbed facies and cyclic sedimentation of the Windsorian Stage (Middle Carboniferous), Maritime Provinces; Canadian Jr. Earth Sci., V. 6, pp. 1037-1066.

88. Sheridan, R.E. and Drake, Ch. L. 1968
Seaward extension of the Canadian Appalachians; Canadian Jr. Earth Sci., V. 5, pp. 337-373.

89. Stacy, M.C. 1953
Stratigraphy and paleontology of the Windsor Group in parts of Cape Breton Island, Nova Scotia; N.S. Dept. Mines, Mem. 2.

90. Stevenson, I.M. 1958
Truro map-area, Colchester and Hants Counties, Nova Scotia; Geol. Surv. Canada, Mem. 297.

91. ——————, 1959
Shubenacadie and Kennetcook map-areas, Colchester, Hants and Halifax Counties, Nova Scotia; Geol. Surv. Canada, Mem. 302.

92. Teichmüller, M. 1962
Die genese der Kohle; 4th Carboniferous Congress, Heerlen, 1958, V. III, pp. 699-722.

93. ——————, and Thomson, P.W. 1958
Vergleichende mikroskopische und chemische Untersuchungen der Wichtigsten Fazies - Typen im Hauptflötz der niederrheinischen Braunkohle; Fortschr. Geol. Rheinld. u. Westf., Bd. 2, pp. 573-598.

94. van de Poll, H.W. 1970
Stratigraphical and sedimentological aspects of Pennsylvanian strata in southern New Brunswick; Unpubl. Ph.D. thesis, Univ. of Wales, Cardiff. U.K.

95. Weeks, L.J. 1948
Londonderry and Bass River map-areas, Colchester and Hants Counties, Nova Scotia; Geol. Surv. Canada, Mem. 245.

96. ——————, 1954
Southeast Cape Breton Island, Nova Scotia; Geol. Surv. Canada, Mem. 277.