CHAPTER 1
INTRODUCTION

Nova Scotia is located in Southeastern Canada and borders on the major shipping routes of the Atlantic Ocean (Fig. 1-1). The Province has many seaports including two excellent ice-free deep water ports, Halifax and the Strait of Canso.

Although metallic minerals including gold, copper, lead and zinc have been mined to some extent, the nonmetallic and industrial mineral industry has made a far more significant contribution to the economy of the Province. This industry is based largely on the mining of gypsum, salt and limestone deposits found primarily in rocks belonging to the Lower Carboniferous Windsor Group and coal from Upper Carboniferous strata. Barite and celestite are also important minerals produced from the Windsor Group. At present, salt production is confined to the underground mine at Pugwash operated by the Canadian Salt Company Limited and the brining mine operated by Domtar Chemicals Limited (Sifto Salt Division) at Nappan, Cumberland County. Nova Scotia's large salt deposits gave it an important mineral resource base for the development of new mines, chemical industries, and underground storage structures.

The study presented in this report was undertaken to update the locations, limits, and structural configurations of Nova Scotia's deposits by reviewing available data. The major source of these data are the mineral assessment files of the Nova Scotia Department of Mines and Energy that contain, for the most part, unpublished reports submitted by exploration companies. Less abundant, but very important data are also available in a few published papers on salt geology in Nova Scotia.

Salt deposits are located and defined by the direct methods of exploratory drilling and/or the locating of salt springs, and indirectly by gravity surveys. The Nova Scotia Research Foundation Corporation has been instrumental in a systematic regional gravity survey of potential salt areas throughout Nova Scotia. An index map of available gravity coverage is presented in Appendix 4.

The following study has been organized by region, area, deposit or occurrence. The files used to prepare this compilation are available at the Nova Scotia Department of Mines and Energy, Halifax. The method of documentation is shown on Table 1-1.

The well documented stratigraphic and structural complications associated with Nova Scotia's salt structures, together with the lack of sufficient surface and subsurface data, make accurate detailed interpretations of many deposits and occurrences extremely difficult. Exceptions are the detailed work by Evans (1972) on the complexly deformed Pugwash Mine geology and the relatively undisturbed Shubenacadie-Stewiacke deposit described by Boehner (1980a).

The writer examined diamond-drill cores containing salt in the Shubenacadie-Stewiacke area and the Antigonish area. All other drillhole logs have been extracted from exploration companies geologists' logs and reports in assessment files. This report is part of the Mineral Resource Inventory Program. It outlines the available geological data on the salt resources in the Province and constitutes a data base from which more detailed work can be extended. Subsequent reports on individual deposits and occurrences will be prepared as the data become available.

HISTORICAL BACKGROUND

Major contributions to understanding the stratigraphy, paleontology and structure of the Carboniferous succession, in particular the Windsor Group in Nova Scotia and Atlantic Canada, were made by W. A. Bell and other geologists with the Geological Survey of Canada. These studies have formed the basis of the understanding of Carboniferous strata. Early workers who have made major contributions to the field of salt geology in Nova Scotia include: Bell (1944, 1958), Sage (1954), Stacey (1953), Hayes (1920, 1931), Chambers (1924), Cole (1926, 1930a,b), Ellsworth (1926), Norman (1932b, 1935) and Bancroft (1938). More recent work includes: Evans (1970a,b,c, 1972), Howie (1979), Goudge (1967), Goodman (1952), Shea (1970), Bidgood (1970), and Bidgood and Blanchard (1967).

An early reference to salt and salt springs in Nova Scotia was made by Haliburton (1829) in historical accounts of several areas including West River of Pictou (1829, p. 58), River Philip (1829, p. 37), Black River near Springhill (1829, p. 68 and 434) and the upper end of the Stewiacke Valley (1829, p. 36 and 37). Detailed descriptions and locations, however, were not reported.

Another early reference to salt and salt springs in Nova Scotia was made by Gesner (1849, p. 264-265) in a general outline of the industrial resources of the Province. Gesner referred mainly to the abundance of springs in Hants County and parts of Colchester County. No specific statements with regard to locations and brine composition were made.

Dawson (1868, p. 276 and 349) reported that brine springs occurred in several parts of Nova Scotia including Walton and Antigonish. Detailed descriptions of their location and composition were not mentioned.

The earliest recorded attempt to mine salt in Nova Scotia occurred in 1813 near Salt Springs, Pictou County. Cole (1930b, p. 7) reported a 60 m shaft had been sunk to locate the source of salt brine found in small springs and seeps in the vicinity. The venture was unsuccessful, although a few years later a small amount of salt was apparently produced by evaporating the brine.

Salt was reported by How (1869) to have been made from the "Salt Pond" near Antigonish prior to 1866. In 1866, according to How (1869), Dawson (1868) and Fletcher (1887), salt ventures were undertaken at Town Point and in Antigonish

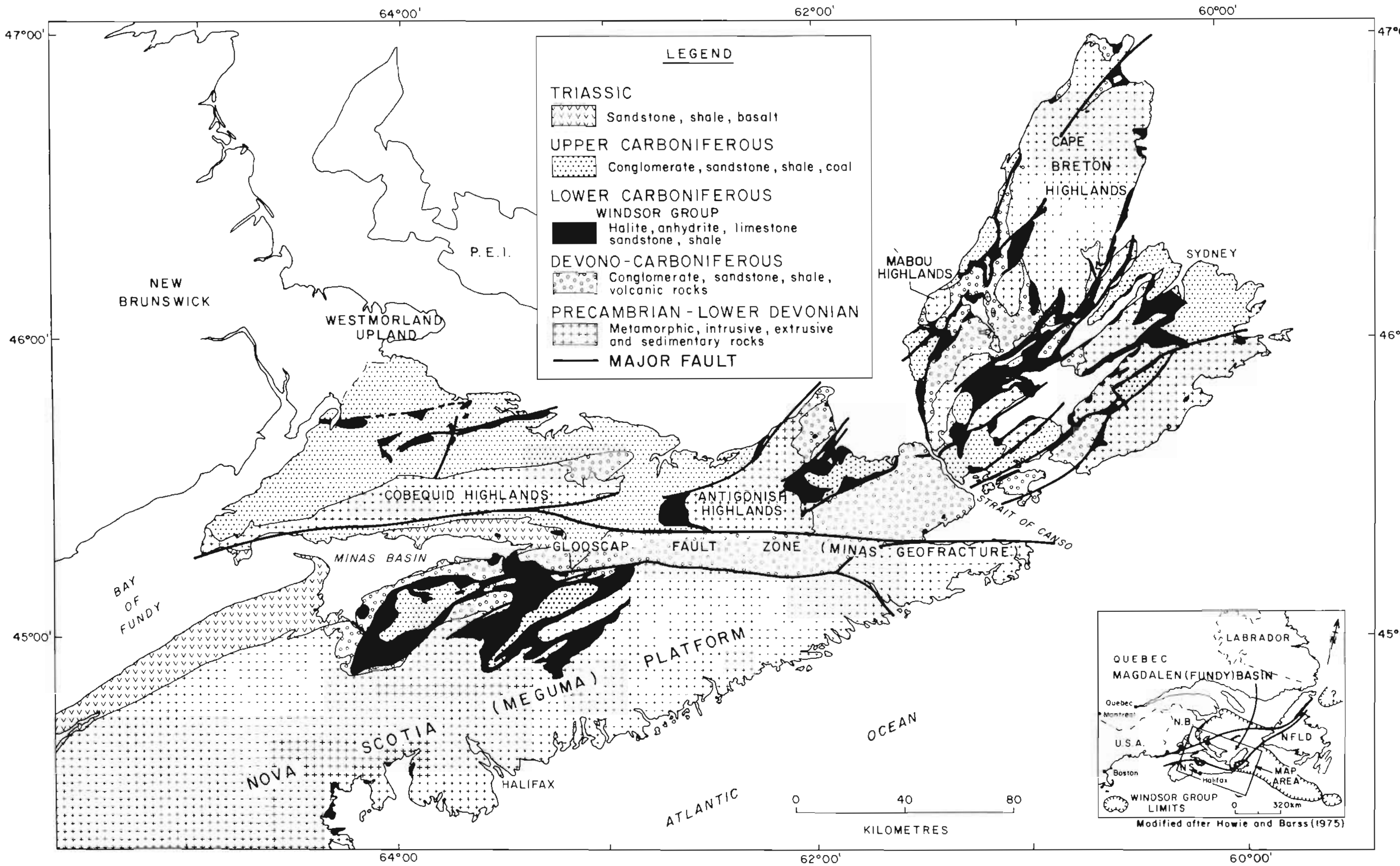

Figure 1-1. General geology and location map, Nova Scotia.

Table 1-1. Nova Scotia Department of Mines and Energy salt files and sub files (sub files colour coded).

SUB FILE 1: Historical Background

NTS Code, Occurrence Name

SUB FILE 2: Geography and Physiography

1:50 000 topography map showing location
Summary of existing reports

SUB FILE 3: Geological Data

Copies of geological maps, reports
Location map for drillholes
Copies of all descriptive drill logs
Copies of all graphic drill logs
Mineralogy of the occurrence/deposit
Geometry of the deposit, suggested structural configurations, cross-sections, etc.
Stratigraphic position of the deposit

SUB FILE 4: Geophysical Data

Copies of gravity surveys, regional and local
Gravity cross-sections
Reports of gravity interpretation
Copies of all available magnetometer surveys
Down-hole geophysics - copies of all logs

SUB FILE 5: Geochemical Data

Types of analyses: brine, whole-rock, salt springs, etc.
Standard format, list of elements, oxides, etc.
Retabulation of all available data

SUB FILE 6: Economic Considerations

(Table form)
Economic minerals present
Approximate depth
Approximate dimensions
Average grade
Proven reserves
Possible reserves
Current utilization
Comments

SUB FILE 7: Source Documents

Bibliography including NSDME assessment file numbers.

SUB FILE 8: Assessment of File Quality

Data type (quantitative, qualitative, geological, geophysical, geochemical).
Insufficient-sufficient
Questionable-reliable
Data update
Utilization planning

by Josiah Deacon, manager at the Nova Scotia Salt Works and Exploration Company. Brine suitable for salt production was encountered in the Antigonish borings, but the quantity and quality of the brine decreased and subsequent boring was unsuccessful in reaching suitable brine. The operation was abandoned and no further developments were reported.

Salt was also reported by How (1869, p. 144) to have been manufactured at Springhill, Cumberland County, in 1867. Details about the operation are sketchy, however, it is assumed to have been abandoned with little significant production.

In the Malagash area in 1912, Peter Murray obtained a flow of salt water in a water well borehole at a depth of approximately 25 m. The salt water obtained was analyzed by Cole (1930b) who reported a nearly saturated salt (NaCl) brine. This incident, together with the presence of salt springs in the vicinity, prompted further drill exploration by Chambers and McKay of New Glasgow in 1917. Twelve boreholes were sunk and brine was encountered in six, at depths ranging from 26 to 34 m. Based upon this success, a diamond-drill hole was put down and intersected salt between depths of 29 and 53 m. A shaft was subsequently sunk nearby, reaching salt at a depth of 26 m. The Malagash Salt Mine was developed in this deposit and was an active producing mine between 1920 and 1959.

A report on the potash possibilities of Nova Scotia sponsored by Imperial Chemical Industries Limited of New York, was published by Hayes (1931). This comprehensive report on the saline rocks and springs in Nova Scotia forms an excellent compilation of available data.

In drilling for petroleum in 1931, the Imperial Oil Company (Amherst No. 1) penetrated a thick deposit of salt at Nappan near Amherst, Cumberland County. Between 1942 and 1944 the Nova Scotia Department of Mines carried out a drilling program to define the salt deposit at Nappan Station near the Amherst No. 1 drillhole. Between 1945 and 1947, Sun Oil Company Limited drilled Sunoco Nos. 1 and 1A and also intersected a thick salt zone in the same area. In 1946 Maritime Industries Limited drilled brine production wells into the salt deposit at Nappan and a brining plant was installed. The mine is presently operated by the Sifto Salt Company (Domtar).

In 1952-53 the Nova Scotia Department of Mines drilled several holes in the Southside Harbour area near Antigonish exploring for salt. The program was sponsored by the Nova Scotia Department of Trade and Industry to evaluate the potential development of a soda ash industry. A large mass of salt was intersected, but the project was terminated. Further drilling in the vicinity was undertaken in 1969 by Novasel Ltd. A single diamond-drill hole was sunk in which a thick section of salt was intersected, but again the project was abandoned because of unfavourable economic conditions.

In the later years of the operation of the Malagash Salt Mine, difficulties with haulage, ore grade and cracked mine support pillars forced the Malagash Salt Company to explore for another salt deposit. Exploration drilling was undertaken in Cumberland and Antigonish Counties and resulted in the discovery of the Pugwash salt deposit near Pugwash Harbour. By 1959, production began at the Pugwash deposit, and the Malagash Mine was phased out and abandoned. The Pugwash Mine is presently operated by the Canadian Salt Company Ltd. A summary of annual salt production in Nova Scotia is presented in Figure 1-2.

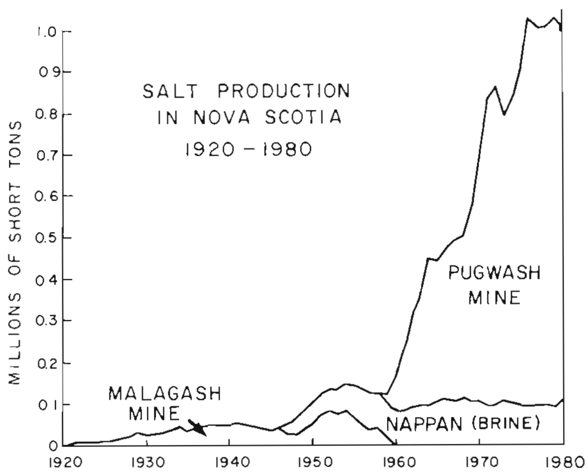

Figure 1-2. Summary of annual salt production in Nova Scotia between 1920 and 1980.

In 1966 the Atlantic Development Board sponsored a potash exploration program in Cumberland County, Nova Scotia. Specific targets were the potash zones found in the Malagash Salt Mine to the deeper parts of the Malagash Anticline towards the west. Four holes were drilled in the Malagash-Wallace area and of these, two intersected potash mineralization at depth. Excessive depths, low grades, and thin mineralized zones have discouraged additional drilling.

The Strait of Canso area has been explored both for potential underground petroleum storage and for a salt brining mine. Dow Chemical Company has developed an underground storage cavern at Port Richmond, 10 km east of Port Hawkesbury. Home Oil Canada Limited et al. has explored the McIntyre Lake area, 6.5 km northeast of Port Hawkesbury, for potential development of underground storage facilities. Domtar has planned the possible development of a brining mine at Kingsville, 20 km north of Port Hawkesbury. Each of these projects is presently in a state of deferment pending improvement in the economic aspects of the respective ventures.

PROPERTIES, OCCURRENCE AND USE OF SALT

Halite, the mineralogical name for salt, is a chloride of sodium with the chemical formula NaCl (Na 39.34 weight per cent, Cl 60.66 weight per cent). Halite is an isometric mineral most commonly occurring in nature as rock salt, a granular crystalline mass comprised mostly of the mineral halite (Hurlbut, 1971). Because of its simple structure, halite was the first mineral to be analyzed by X-rays. Pure halite is transparent to translucent and is colourless to white, but when impure it may have shades of red, yellow, grey or blue. It typically displays a perfect cubic cleavage, has a Mohs hardness of 2 (scratched by a finger nail), and a specific gravity of 2.168 (pure NaCl) placing it among the lightest of the naturally occurring rock forming minerals. Halite is very soluble in water: 35.7 parts per 100 parts water at 0°C, and 39.8 parts per 100 parts water at 100°C (Lefond and Jacoby, 1975).

Halite is a common mineral occurring in a variety of geological circumstances. Halite occurs in rocks that range in age from Precambrian to Recent throughout the world. Halite is the most abundant dissolved constituent of seawater, estimated at 18.76 million km^3 (Lefond and Jacoby, 1975).

Rock salt occurs as very thick deposits in the Windsor Group (Early Carboniferous) of Atlantic Canada, both on land and in the offshore areas. These salt deposits are part of an extensive marine evaporite succession with associated anhydrite ($CaSO_4$) and locally with the potash salts sylvite and carnallite (KCl and $KCl.MgCl_2.6H_2O$), located notably in the Sussex and Salt Springs areas of New Brunswick. The salt deposits of Atlantic Canada were originally bedded deposits, precipitated from seawater in a series of restricted basins which formed in the Fundy Basin (Bell, 1929, 1958) or the Fundy Aulacogene (Keppie, 1977) during Early Carboniferous time. The halite is interstratified with anhydrite and gypsum, marine limestone and dolostone and red-green terrigenous clastics. Most have since been modified during tectonism into pillows, anticlines and diapirs-domes with variable structural complexities.

Salt or halite has had a long history of domestic and industrial use. Its earliest uses were related to food preparation and preservation, although a much broader utility exists at present. A large portion (39.1% in 1976 and 23.6% in 1979) of salt consumed in Canada was used in chemical industries (Boyd, 1977). Products include chlorine, caustic soda, hydrochloric acid, sodium metal, and over 30 other basic chemicals. These basic chemicals in turn were used in the manufacture of about 14 000 additional chemicals.

In northern climates salt is used for snow and ice control on highways. This use comprised 52.5% of the total salt consumed in Canada in 1976 and 67.7% in 1979.

Food processing and related industries including fishing, meat packing, tanning and agriculture consume the major share of the remainder (7% in 1976 and 8.7% in 1979). Slightly over 1% is used in the pulp and paper and textile industries (Boyd, 1977).

Salt production in Canada has ranged from 6.257 million t in 1976 (Boyd, 1976) to 6.918 million t in 1979 (Barry, 1979). The share produced in Nova Scotia during the same period has increased from 15% to 16.6%.

Salt deposits are becoming increasingly important as a host rock in the development of pressurized and unpressurized underground storage structures (Martinez and Thoms, 1977). Constant temperature and humidity, together with its impermeablity, solubility and plastic behaviour, make salt an important resource in developing storage structures. Worked out salt mines and brined deposits can be used for liquid or dry storage of materials such as petroleum products, compressed air and industrial wastes. Deposits presently unsuitable for conventional mining methods may be suitable for creating artificial caverns through solution mining. Petroleum and its liquid and gas derivatives may be stored as strategic reserves or as part of a refinery trans-shipment complex. The Strait of Canso area on Cape Breton Island, with its excellent deep water docking facilities, proximity to frontier petroleum areas, potential market areas, and nearby salt deposits, appears to be ideally situated for such underground storage structures. The process, however, results in the loss of the salt as a future mineral reserve for mining operations, and its use should be carefully assessed.

GENERAL GEOLOGY OF NOVA SCOTIA

Nova Scotia may be broadly divided into three major geological areas (Figs. 1-1 and 1-3): southern Nova Scotia, northern Nova Scotia and Cape Breton Island. The Glooscap Fault System (Minas Geofracture of Keppie, 1982a), which trends westerly from Chedabucto Bay to the Bay of Fundy, separates southern Nova Scotia from northern Nova Scotia and Cape Breton Island. A summary of the major stratigraphic and tectonic events affecting these areas is presented in Figure 1-3.

The Precambrian to Early Devonian rocks are generally penetratively deformed by one or more of three principal tectonic events: the Precambrian Avalonian Orogeny, the Ordovician Taconian Orogeny and the Devonian Acadian Orogeny. The major orogenies have been attributed to the collision of various plates (Keppie, 1977, 1982a,b). The area to the south of the Minas Geofracture (Keppie, 1982a) is composed of Lower to Middle Paleozoic rocks of the Meguma Group. These rocks were folded during the Devonian Acadian Orogeny into northeasterly to easterly trending upright folds. According to Keppie (1977), basic dykes and sills were emplaced during the Silurian prior to the deformation. Granites intruded the folded and deformed rocks during Devonian and Early Carboniferous time. Throughout the Carboniferous, nonmarine and minor marine sedimentation occurred upon the older rocks in downwarped and faulted areas. The eastern and western ends of the Minas Geofracture are marked by Triassic Fundy Group sedimentary and volcanic rocks in grabens or half-grabens.

The area to the north of the Minas Geofracture is geologically more complex and

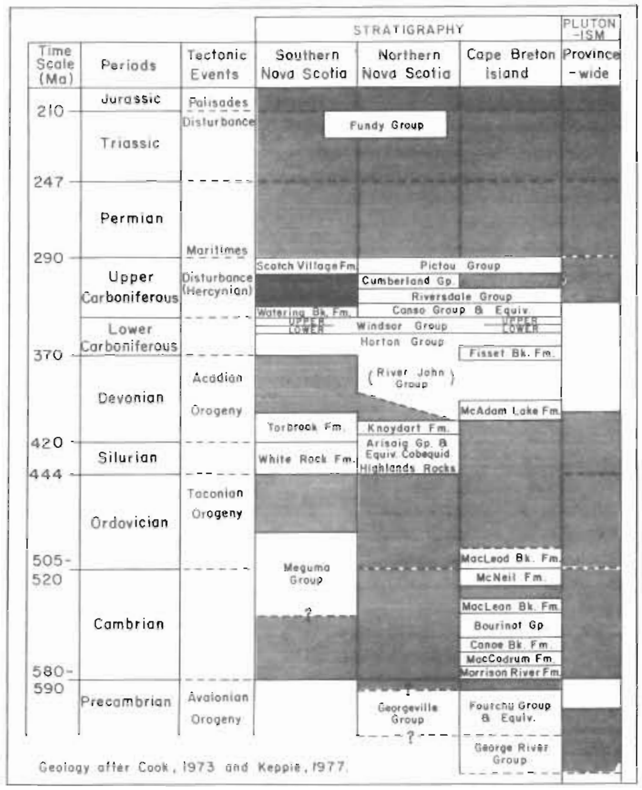

Figure 1-3. General stratigraphy and tectonic events of Nova Scotia.

difficult to generalize. On mainland Nova Scotia, Lower to Middle Paleozoic with minor Proterozoic rocks occur in two major horst structures known as the Cobequid and Antigonish Highlands (Fig. 1-1). Adjacent to these blocks, very thick successions of Permo-Carboniferous nonmarine and minor marine sediments occur in large and small faulted and folded rift basins and/or synclinoria. Hadrynian or older Proterozoic sedimentary and volcanic rocks outcrop in much of the northern Cape Breton Highlands and along southeastern Cape Breton. Smaller basement horsts are also found scattered over the remaining area. These rocks are overlain in southeastern Cape Breton by a Lower Paleozoic sequence of Cambrian sedimentary and volcanic rocks. Granitic and minor basic plutons of Carboniferous, Devonian, and possibly locally Ordovician or older age intruded the older deformed rocks. Similar to mainland Nova Scotia, a very thick succession of Carboniferous nonmarine and minor marine sediments occur in faulted and folded basins and synclinoria that developed adjacent to and on top of the older rocks. These occur in the Canso-Bras d'Or, Sydney, Mabou and Cheticamp-Margaree areas. Much of the bedrock in Nova Scotia has been covered by a thick mantle of Pleistocene glacial deposits.

GENERAL GEOLOGY OF SALT IN NOVA SCOTIA

The majority of the salt deposits and occurrences in Nova Scotia are confined to the Lower Carboniferous Windsor Group (Fig. 1-4), which is widely distributed throughout Atlantic Canada. However, in rocks of the Horton Group in some areas such

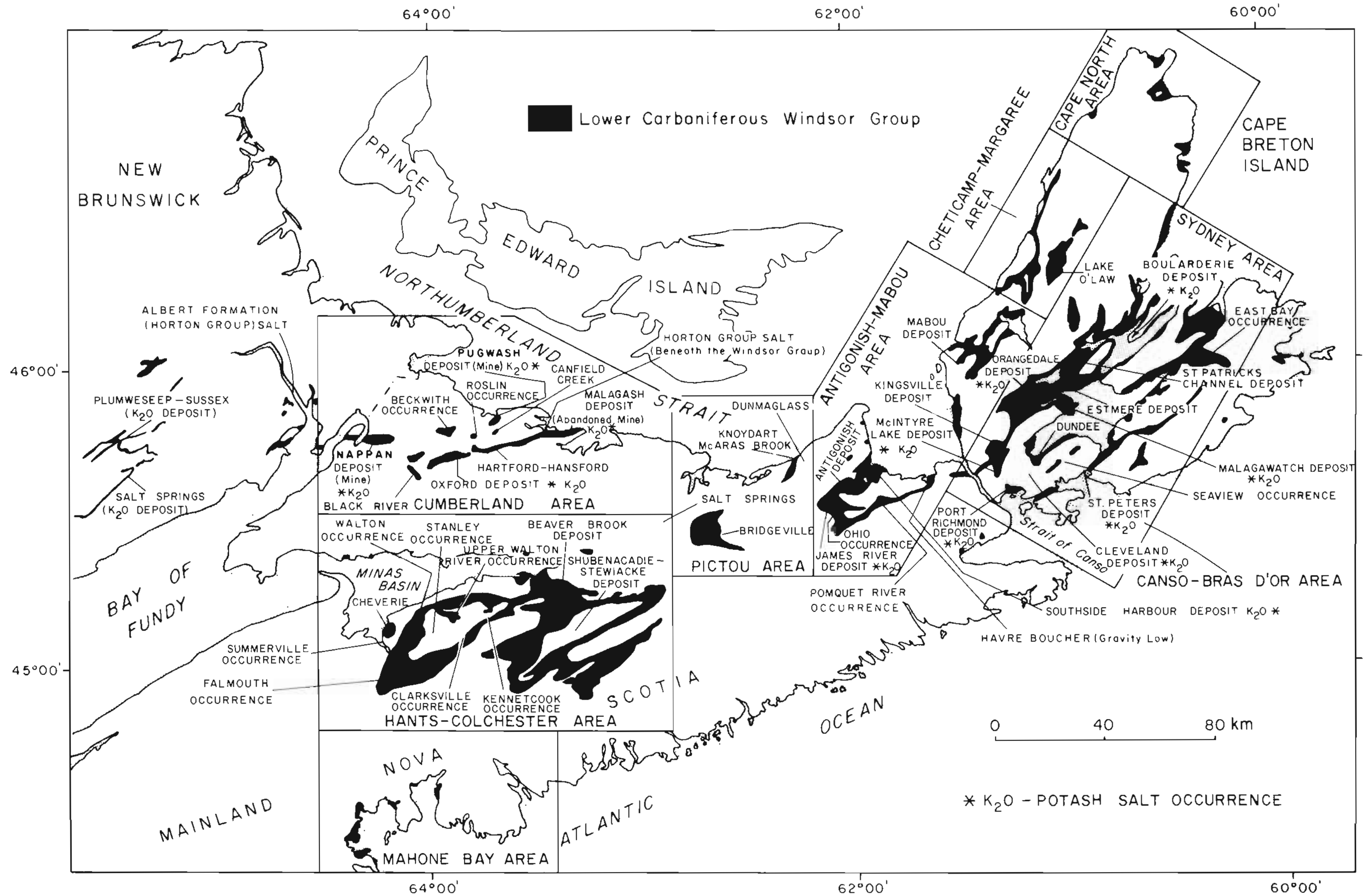

Figure 1-4. Windsor Group outcrop distribution, salt areas and deposits in Nova Scotia.

as the Cumberland area, minor amounts of salt occur in a situation similar to that in New Brunswick (Hamilton, 1961). Exploration activity to date has not been attracted to the potential continental evaporite deposits within pre-Windsor Group strata. Anomalous salt springs and saline water flows at Cheverie, Hants County, and Dunmaglass, Antigonish County (Fig. 1-4) may originate from pre-Windsor evaporites, although a fault related connection with Windsor Group evaporites is the preferred explanation.

The Windsor Group consists of interstratified marine and nonmarine sediments deposited in a complex subsiding basin system called the Fundy Basin, Fundy Epieugeosyncline (Bell, 1929, 1958), Fundy Aulacogene (Keppie, 1977) or Magdalen Basin (Keppie, 1982a,b). The Windsor Group is underlain by a thick sequence of coarse and fine terrigenous derived clastic rocks belonging to the Lower Carboniferous Horton Group although rocks assigned to this Group are as old as Middle-Late Devonian (Howie and Barss, 1975). These rocks were deposited in subsiding areas adjacent to and on top of the older deformed metamorphic and intrusive Acadian Orogen rocks whose ages range from Precambrian (Hadrynian) to Middle Devonian. The Windsor Group rocks represent the only major marine deposits in the Carboniferous sequence (Fig. 1-5) which began and ended with deposition of thick continental sediments.

Generally more than 50 per cent of the sedimentary rocks in the Windsor Group consist of evaporites, primarily anhydrite, gypsum, and halite with lesser but economically significant quantities of potash. These marine evaporite deposits precipitated from saturated seawater. The deposits occur as thick and thin beds, rythmically alternating and often intimately associated with fossiliferous marine limestone and dolostone, and red to maroon and green terrigenous clastic sediments.

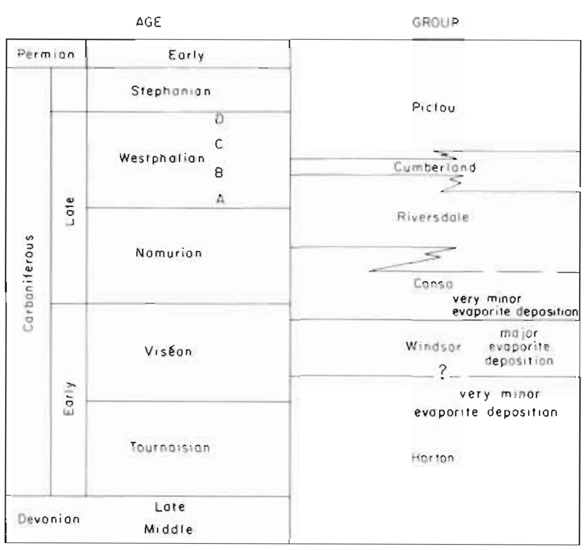

Figure 1-5. Upper Paleozoic stratigraphy and evaporites in Atlantic Canada.

The Windsor Group is overlain in most areas both conformably and unconformably by a locally very thick sequence (up to 5000 m) of Upper Carboniferous nonmarine sediments consisting primarily of interbedded sandstone, siltstone, shale, and conglomerate. Groups recognized in succession from oldest to youngest are the Canso, Riversdale, Cumberland, and Pictou Groups (Fig. 1-5). The major coal deposits in Nova Scotia are found in rocks assigned to the Cumberland and Pictou Groups. A large number of formation names have been applied to subdivided units within groups and a summary of these is included in Howie and Barss (1975).

WINDSOR GROUP MAJOR CYCLES

The distribution, thickness and stratigraphic position of salt and potash within the Windsor Group were generally poorly understood until deep core drilling was conducted by mineral exploration companies in the deeper parts of the Windsor Group in the Hants-Colchester area during the mid 1970's. Prior to this, deep drilling was scarce and the holes were rarely cored completely. They were frequently located in structurally complicated areas making the stratigraphic succession difficult to determine. Detailed stratigraphic studies in the extensively drilled Shubenacadie and Musquodoboit Basins in the eastern part of the Hants-Colchester area by Giles and Boehner (1979, 1982a,b) revealed that salt (halite) occurred in association with anhydrite and siltstone at several stratigraphic positions within five major cycles of the Windsor Group (Figs. 1-6, 1-7, 1-8).

The three major cycle system originated by Giles (1978) was applied by Boehner (1984) to the Shubenacadie and Musquodoboit Basins (Figs. 1-6 and 1-7, Sections 2 and 3). It was subsequently refined and enlarged to five major cycles by Giles (1981c) who applied the system throughout Nova Scotia. The major cycle system is based primarily on detailed lithostratigraphy and paleontological data, and on comparisons to the British Dinantian Stages; it represents major transgressive-regressive phases within the Windsor Group. According to Giles (1981b), the lower boundaries of the major cycles coincide closely with lithostratigraphic, macropaleontologic, and micropaleontologic boundaries. He further concluded that the cycles were bounded by approximate time planes. To generalize the complicated lithostratigraphic nomenclature of the Windsor Group in Nova Scotia, the five major cycle system is used in this paper. The major cycle system is introduced and outlined from the Shubenacadie and Musquodoboit Basins and then extended to other Windsor Group areas in Nova Scotia.

Major Cycle 1

The major salt in the Shubenacadie Basin (Figs. 1-6, 1-7, 1-8) occurs as part of Major Cycle 1, an evaporite dominated sequence up to 500 m thick, comprising in ascending order: a thin laminated basal carbonate (3-50 m of dolostone) which locally has a thick bank facies, a thick massive to stratified anhydrite (160-300 m

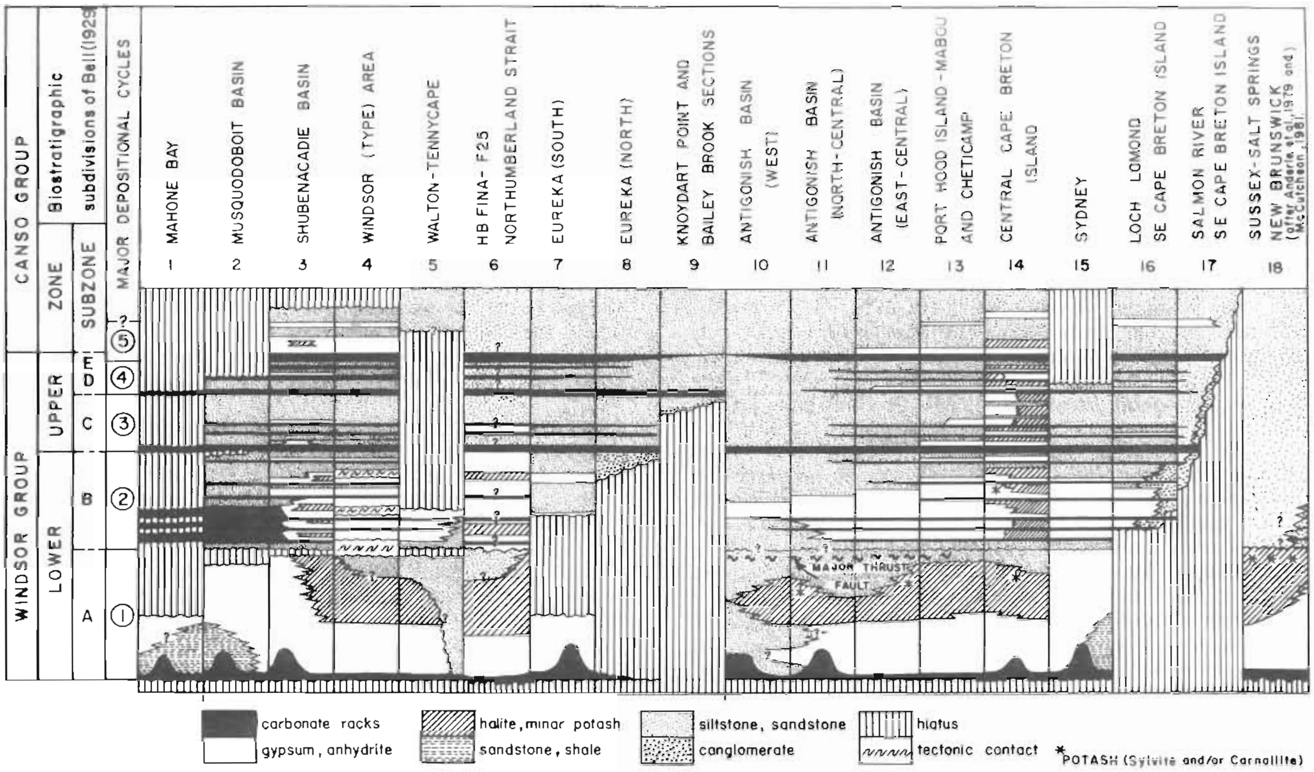

Figure 1-6. Lithostratigraphy and major cycles of the Windsor Group in Nova Scotia (see Fig. 1-7 for locations).

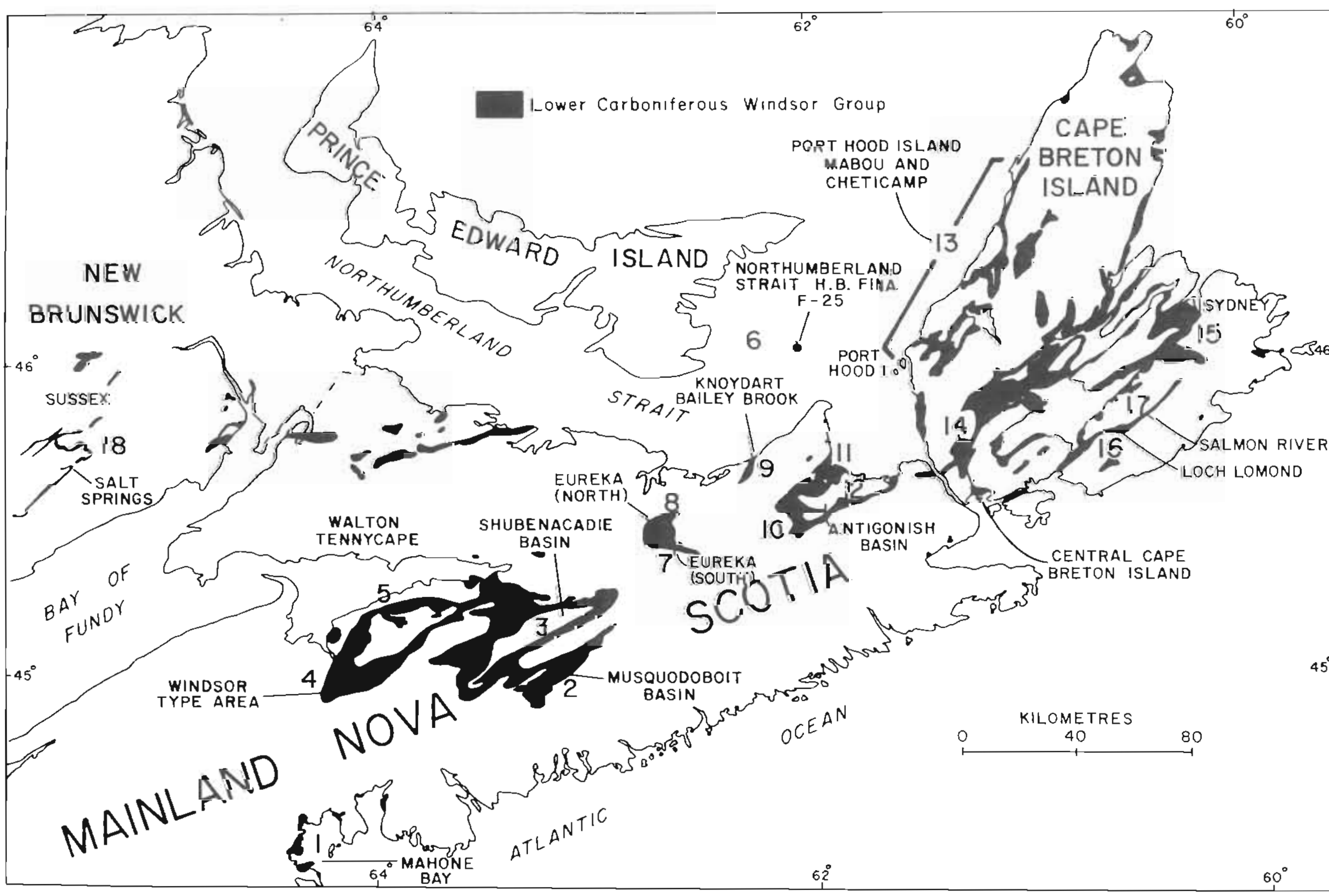

Figure 1-7. Location map for major cycle sections in Nova Scoita (numbers refer to Fig. 1-6).

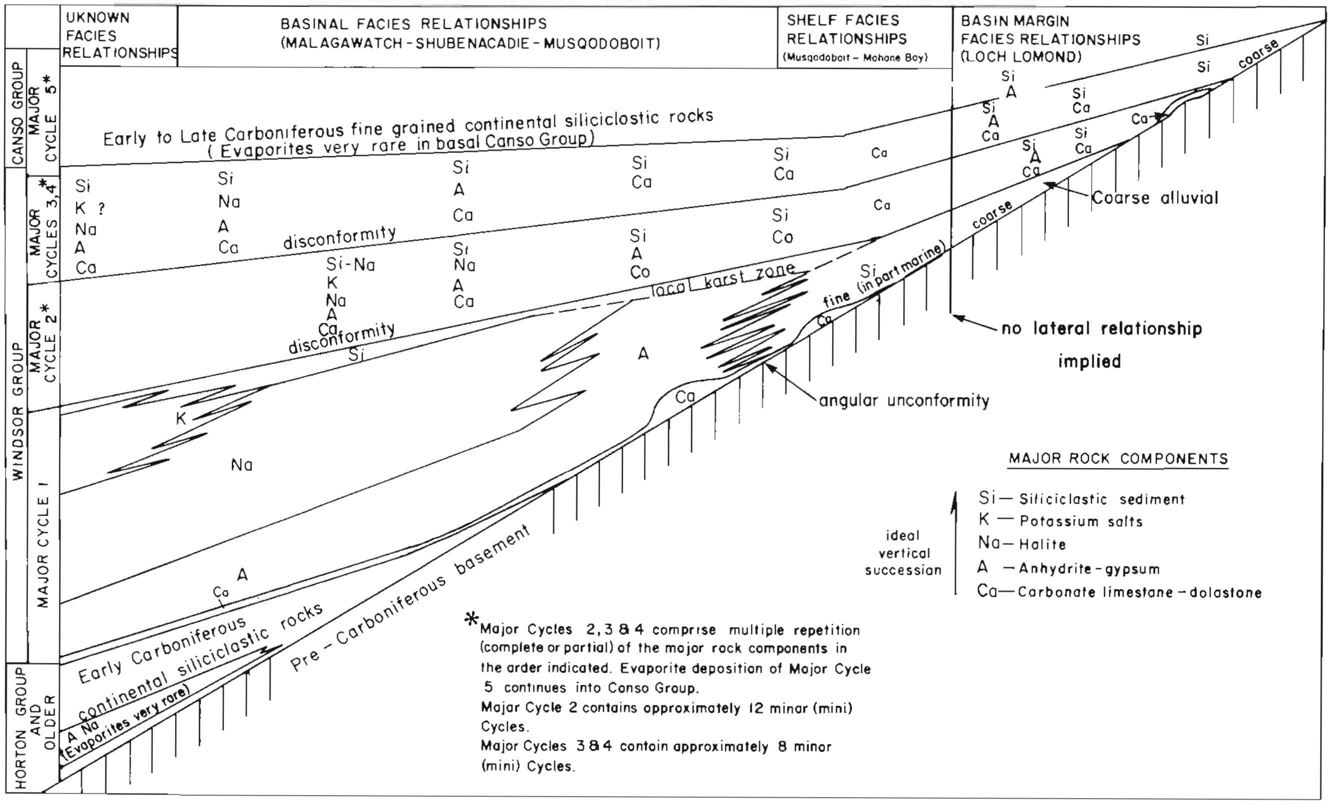

Figure 1-8. Schematic representation of some Windsor Group facies relationships.

thick), and stratified halite with minor siltstone and anhydrite (up to 300 m thick). In addition, a mixed siliciclastic facies, representing nearshore marine deposition, was recognized in the adjacent Musquodoboit Basin as a lateral equivalent of the anhydrite (Figs. 1-6, 1-7, and 1-8). The classic vertical (and to a lesser degree lateral) succession of marine carbonate and evaporites ranging up to halite is well represented in this area. The halite facies is confined to the Shubenacadie Basin and typically comprises banded-bedded halite with alternating light coloured pure and dark impure couplets. It also has well developed displacement and crust-like halite (shallow subaqueous to subaerial?) closely associated with green siltstone interbeds near the upper half of the section. Anhydrite interbeds (up to 5 m) are the dominant nonhalite impurity in the lower half of the halite facies. The top of Major Cycle 1 in the Shubenacadie and Musquodoboit Basins is a disconformity with karstification of the anhydrite facies at the basin edge and local reworking of anhydrite.

Based upon facies relationships, paleogeographic and paleotopographic reconstructions, Boehner (1984) concluded that Major Cycle 1 recorded very rapid marine trangression (possibly nearly instantaneous) into a pre-existing subsea level continental basin with water depths possibly up to 200 m. The thin basal laminite carbonate, although generally sparsely fossiliferous, had locally developed fossiliferous banks at higher elevations. The absence of significant transgressive facies indicates rapid transgression. The basal carbonate (cryptalgal laminite and bank facies) succession mainly records salinity stratification and progressive increase in salinity (Geldsetzer, 1978; and Giles et al., 1979). Increasing salinity produced the successive deposition of anhydrite then halite, which was localized in a shrinking basin adjacent to a contemporaneous subaerially exposed anhydrite surface. Major Cycle 1 in the Shubenacadie and Musquodoboit Basins is interpreted as generally representing regression, restriction and increasingly saline subaqueous evaporite deposition in a preformed basin.

Major Cycle 2

Major Cycle 2 in the Shubenacadie and Musquodoboit Basins is up to 160 m thick and overlies the thick evaporite sequence of Major Cycle 1. It is an assemblage of up to 12 minor transgressive-regressive cycles (minicycles) 1-15 m thick, consisting of laterally extensive transgressive-regressive marine carbonates, continental redbeds (in subequal proportions) with a variable, but generally dominant proportion of evaporite (greater than 50%) including anhydrite and minor halite. A typical saline minicycle comprises in ascending order: transgressive then regressive carbonate facies, anhydrite, halite, ± redbeds (Fig. 1-7). Boehner (1984) described the anhydrite as ranging from nodules in matrices of siltstone or carbonate grading to coalescing nodular mosaic. The anhydrite associated with stratified halite is massive to locally laminated and halitic. The nodular anhydrite both in situ and as clasts was interpreted by Boehner (1984) as recording a diagenetic sabkha-type origin in low relief prograding coastal mud flats. The closely associated laminated and massive anhydrite and bedded halite were inferred to have been precipitated in shallow hypersaline pans and lagoons spatially associated with the sabkha environment.

Major Cycles 3, 4 and 5

In the Shubenacadie and Musquodoboit Basins Major Cycles 3, 4 and 5 disconformably overlie Major Cycle 2. Major Cycle 5 includes the highest Windsor Group marine carbonate member and the transitional evaporites (anhydrite and halite) locally present at the base of the Canso Group. These Major Cycles, comprising up to 9 minicycles, are lithologically similar to Major Cycle 2 and have a combined thickness of up to 160 m. They differ from Major Cycle 2 mainly in the decreased proportion of evaporite (less than 30%). Typical saline minicycles include in ascending order: transgressive then regressive carbonate facies, anhydrite and redbeds (Fig. 1-8). Halite is known only in Major Cycle 5 in the Shubenacadie Basin. The continuation of evaporite deposition including anhydrite and halite of Major Cycle 5 into post Windsor Group rocks (Canso Group) is interpreted as representing the terminal phase of marine invasion and evaporite deposition in restricted continental successor basins with uncertain marine influence.

The dramatic change from the single progressive evaporite sequence of Major Cycle 1 to the repeated minicycles within Major Cycles 2 to 5 was interpreted by Boehner (1984) to have resulted from the basin infilling and topographic leveling by the thick evaporites of Cycle 1. The resulting surface of low relief and gentle slope favoured shallow water and diagenetic evaporite deposition during regressive episodes following repeated marine invasions. Boehner (1984) recognized decreased and more localized evaporite deposition within successively younger major cycles of the Shubenacadie and Musquodoboit Basins.

Major Cycles Distribution and Correlation

The major cycle framework outlined from the Shubenacadie and Musquodoboit basins is generally applicable to many Windsor Group outcrop areas in Nova Scotia (Figs. 1-6 and 1-7). Major facies changes and stratigraphic onlap locally complicate the picture, especially in areas near basement blocks such as Mahone Bay, Eureka and Loch Lomond (Figs. 1-6, 1-7, Sections 1, 8 and 16; and Fig. 1-8). Typical Major Cycle 1 rocks are widespread throughout Nova Scotia and are well represented in the Antigonish-Mabou, Canso-Bras d'Or and Sydney areas where their thickness ranges from 300 to 600 m. Redbeds are locally developed in some areas including western Hants-Colchester, Antigonish-Mabou, and Canso-Bras d'Or (Figs. 1-6 and 1-7, Sections 4, 5, 6, 10, 11, 12, 13 and 14). The redbeds are closely associated with the halite facies. Halite is known to occur with Major Cycle 1 in most areas and it forms the most important salt resource in Nova Scotia. Boehner (1980a) reported that the Shubenacadie-Stewiacke deposit in the Hants-Colchester area contains an estimated geological resource of 50 billion t.

Potash salt, sylvite and minor carnallite are known to be associated with halite in Major Cycle 1 in the Antigonish and Canso-Bras d'Or areas (Figs. 1-6, 1-7 and 1-8, Sections 10, 11, 12 and 14). Although encouraging for further exploration, economic quantities have yet to be discovered. Potash salts are not known to occur on the Nova Scotia Platform south of the Minas Geofracture. Major Cycle 1 rocks in this area were inferred by Giles (1981b) to have been deposited adjacent to seaways connected to a major Viséan sea through a shallow marine carbonate shelf on the Nova Scotia Platform. Successive Carboniferous structural basins in a northwesterly direction generally contain increasingly saline evaporite suites indicating significant lateral facies change and important paleogeographic control on evaporite deposition. Paleogeographic reconstructions across the Minas Geofracture are uncertain at this time.

The distribution, thickness and facies variation of evaporites in Major Cycle 1 are unknown in most areas because of the scarcity of deep drilling. Stratigraphic thicknesses of up to 600 m are present in some areas with the thickest sections in the highly deformed saline Windsor Group facies of the Canso-Bras d'Or area. Major Cycle 1 is the major target for potash exploration in Nova Scotia as it is in New Brunswick (Fig. 1-6, Section 18).

The thick halite-anhydrite-siltstone sequence in the highly deformed diapiric Windsor Group in the Cumberland area is of uncertain stratigraphic assignment (Fig. 1-9). Drillhole sections and mine stratigraphic sections (Evans, 1972) are incomplete and their relationship to outcrop sections of Bell (1958) are uncertain. The stratigraphy of the evaporites in the Cumberland area is virtually unknown and therefore stratigraphic comparisons to well established sections in other areas is not yet possible.

The basal Windsor Group in the Anschutz Wallace Station No. 1 well (Fig. 1-9) drilled near Malagash comprises a thick sequence of cherty-siliceous shales. These relatively undisturbed, gently dipping shales may represent deep water sediments. The Cumberland area is geologically important because it is close to the New Brunswick Platform area where economic potash deposits have been discovered in Major Cycle 1 of the Windsor Group (Figs. 1-6 and 1-7, Section 18). Potash salts, sylvite and carnallite have been reported from all known salt deposits in the Cumberland area, but not in economic quantities (Fig. 1-4). Structural complexity and geological uncertainty are major factors that have hindered potash exploration in this area. Potash salts are found in two major settings (Fig. 1-9) associated with the Windsor Group evaporite diapirs: 1) as mudstone-halite breccia and boudins in intensely folded stratified layers, and 2) as remobilized secondary veins and stockworks peripheral to and/or within the diapir. The stratigraphic position of these potash occurrences is unknown.

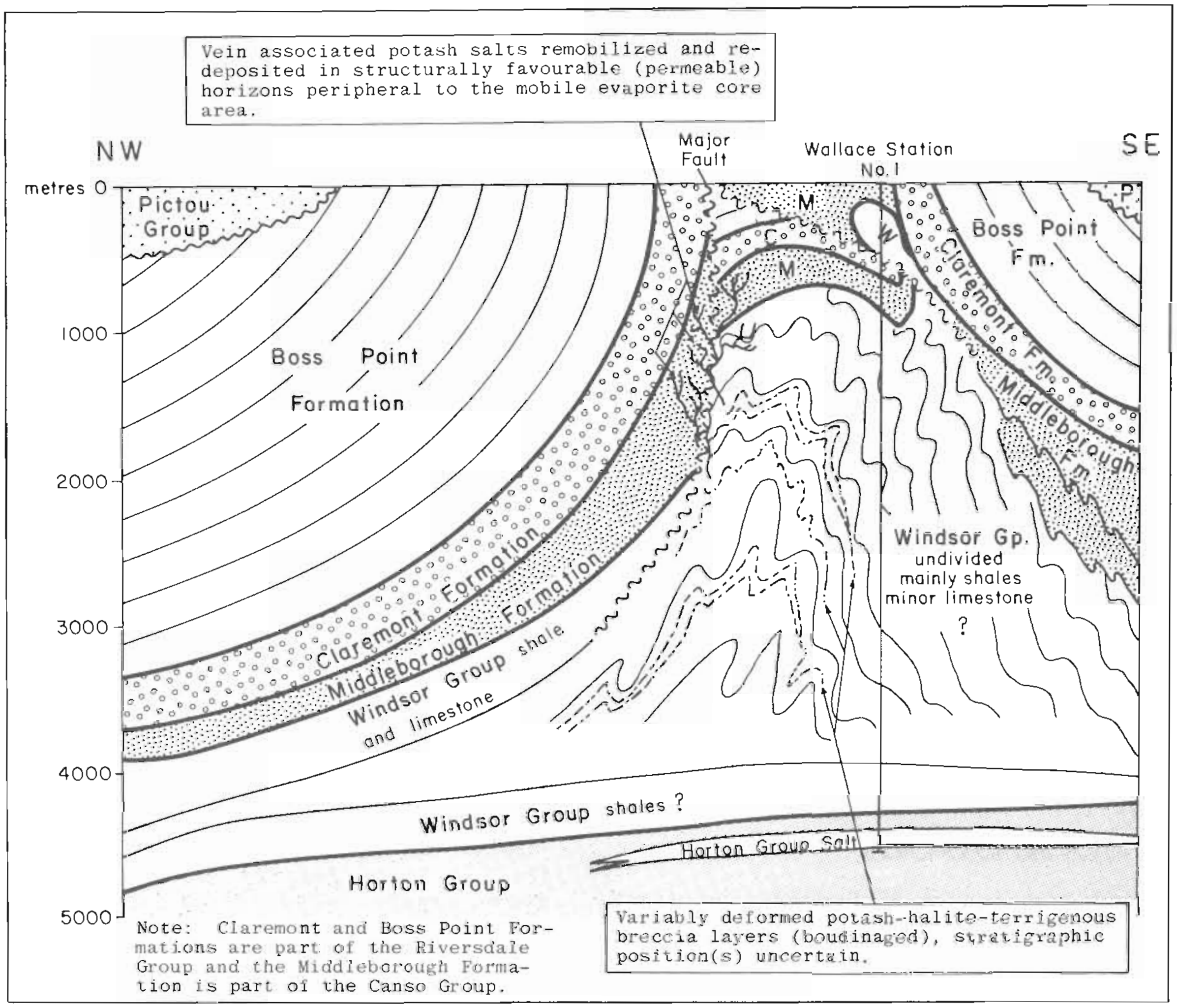

Figure 1-9. Schematic cross-section through the Malagash Anticline illustrating structural complexity of the diapir and settings for potash salts.

Major Cycle 2 is more widespread than Major Cycle 1. Major Cycle 2 displays major facies change regionally ranging from evaporite dominated to terrigenous dominated. It locally oversteps Major Cycle 1 to onlap onto pre-Carboniferous basement rocks (Fig. 1-8) in marginal basin areas including Loch Lomond and Salmon River (Figs. 1-6 and 1-7, Sections 16 and 17, Boehner, 1983). Similar changes were indicated by Giles (1981c) in the Eureka and Mahone Bay areas (Figs. 1-6 and 1-7, Sections 1 and 8). The Mahone Bay area is similar to the Musquodoboit Basin (Fig. 1-6, Section 2). Shallow marine shelf facies in Major Cycles 1, 2 and 3 indicated that these areas may have been proximal to a seaway connecting the Viséan inland sea on the Nova Scotia Platform to the Major Viséan sea to the southeast (Giles, 1981c). The major evaporite deposition appears to have been localized in deeper, more northerly parts of the inland sea.

Halite stratigraphically above Major Cycle 1 was first recognized with several carbonate-anhydrite minicycles within Major Cycle 2 in the Shubenacadie Basin (Figs. 1-6, 1-7, Section 3). The stratified halite and interbedded anhydrite horizons rarely exceeded thicknesses of 15 m, but subsequently thicker and more numerous halite beds have been confirmed in the highly deformed sections in the Canso-Bras d'Or area (Giles, 1981a; and Dekker, 1982a,b). Exploration drilling at McIntyre Lake, Malagawatch and Orangedale has intersected potash (sylvite and minor carnallite) in one carbonate-anhydrite-halite minicycle within Major Cycle 2. The presence of potash, although in subeconomic quantities in at least one horizon in this cycle, was previously unknown and may provide an additional potash exploration target.

Major Cycle 2 at Malagawatch is dominated by halite and is up to three times (500 m versus 160 m) as thick as in the Hants-Colchester area. Approximately 45 per cent of the Malagawatch section is halite and 30 per cent anhydrite. Corresponding sections in the Shubenacadie Basin are 14 per cent halite and 51 per cent anhydrite.

The majority of the increase in statigraphic thickness at Malagawatch is contributed by the halite (230 m versus 22 m).

Major Cycles 3, 4 and 5 are more widely distributed than Cycles 1 and 2 (Fig. 1-7). Onlap relationships have been documented by Boehner (1983) near Loch Lomond and Salmon River (Figs. 1-6 and 1-7, Sections 16 and 17) in southeastern Cape Breton Island and near Knoydart Point in northeastern mainland Nova Scotia (Figs. 1-6 and 1-7, Section 9) by Giles (1981c). Although salt was locally present in Major Cycle 5 in the Shubenacadie Basin it did not occur in Major Cycles 3 and 4. It was found, however, to be a substantial component in Major Cycles 3 and 4 in the Canso-Bras d'Or area. Here the Major Cycle 3 section is nearly four times as thick as corresponding sections in the Shubenacadie Basin (270 m versus 70 m) and consists of 34 per cent halite and 28 per cent anhydrite. Corresponding values are 0 per cent and 10 per cent, respectively, in the Shubenacadie Basin. Similar to Major Cycle 2 in the Malagawatch area, most of the increase in thickness is contributed by the halite.

Unfortunately, data are incomplete to allow comparisons with Major Cycles 3 and 4 in other areas such as Antigonish-Mabou and Cumberland. Salt facies have not been confirmed in Major Cycles 2, 3, 4 and 5 in these areas. Anhydrite is present and the presence of salt (possibly with potash) may be established by deep basin drilling.

SALT DEPOSITS AND OCCURRENCES

The present distribution of Carboniferous rocks in Nova Scotia is controlled by postdepositional tectonism and erosion. These factors, together with high angle transcurrent, dip slip and low angle faulting, make a precise outline of the original sedimentary sub-basins difficult. The relationship of the present structural basins or synclinoria to the original depocentre is sometimes uncertain. For these reasons the salt areas of Nova Scotia described in this report are named as present day geographical and structural areas that may or may not correspond to the original sedimentary sub-basins outlined by Bell (1958).

The five areas with known salt deposits (Fig. 1-4) found in Nova Scotia are the Hants-Colchester, Cumberland, Antigonish-Mabou, Canso-Bras d'Or, and Sydney areas. In addition, there are four areas underlain by Windsor Group rocks where salt may be present, but has not been established by drilling. These include the Mahone Bay, Pictou, Cheticamp-Margaree, and Cape North areas. The salt and potash resources of the Province are shown on Figure 1-10 (in the back pocket).

GENERAL TECTONICS AND STRUCTURAL GEOLOGY

Keppie (1982a) indicated that the Carboniferous rocks in the Magdalen Basin and locally in adjacent areas were deformed between Early Westphalian and Late Triassic times. This deformation was attributed to movement on the Minas Geofracture associated with the Hercynian Orogeny. Deformation within the Magdalen Basin was most intense along its margins and was accompanied by diapiric structures in basinal settings such as the Cumberland area. Subsidiary strike slip and dip slip movement on major systems of northeasterly trending transcurrent faults produced local deformation in narrow Carboniferous areas bounded by fragmented basement blocks. This situation is common in the Canso-Bras d'Or area. Locally severe deformation including gravity sliding occurred on the relatively stable Nova Scotia Platform. In the deeper basins differing fold geometry and structural style may be expected between pre- and post-Windsor Group rocks.

Carboniferous rocks were deposited in two principal tectonic settings: 1) on relatively stable platforms i.e Nova Scotia and New Brunswick Platforms (Fig. 1-7), and 2) within an intervening fragmented pull apart area named the Magdalen Basin (Keppie, 1982b). These settings developed, beginning in the Middle-Late Devonian, as part of transpression tectonics (Keppie, 1982a,b). Prominent transcurrent wrench faulting produced a molassic succession characterized by complicated facies variation and structural complexity. The easily mobilized evaporite deposits of the Windsor Group have locally undergone severe deformation and thickening, often resulting in large wall and plug-like diapiric intrusions. The most severe deformation is characterized by tortuous folding with isoclinal, recumbent to upright geometry, normal and reverse faulting, gravity sliding, and extensive plastic flow of salt and anhydrite rocks. Locally, as in the Cumberland area, unconformities are evident where younger Carboniferous units flank the structure (Fig. 1-9) indicating that the movement occurred over a period of time.

In Nova Scotia, Windsor Group evaporites including salt and associated potash occur in a variety of structural situations that have been classified in Figure 1-11. The locations of salt and potash are based primarily upon the degree of structural complexity and thus each type is part of a continuous spectrum. The structural complexity is controlled largely by location with respect to the major faults, severity of tectonism, volume of salt and depth of burial. The relatively undisturbed stratified deposits (Types A and B) generally occur in the platform synclinoria marginal to the central mobile area (Figs. 1-11, 1-12). At the opposite end of the spectrum, structurally complex halotectonic type deposits resulting from compressive tectonic forces (Halbouty, 1967, p. 2) are represented in the Canso Bras d'Or area (Types C and D). Intensely deformed deposits (at least in the final stage of development) from halokinetic (isostatic) salt movement, (Halbouty, 1967, p. 2) are present in the Cumberland area (Figs. 1-10, 1-11). Here Windsor Group evaporites occur as wall and dome, diapiric anticlinal intrusions. These intrusions appear to be restricted to areas of thick Carboniferous sedimentation and may occur in the Mabou and the Canso-Bras d'Or areas (Figs. 1-10, 1-11).

Moderate to strong deformation is present in the western and northern parts of the Hants-Colchester area, the Antigonish area and parts of

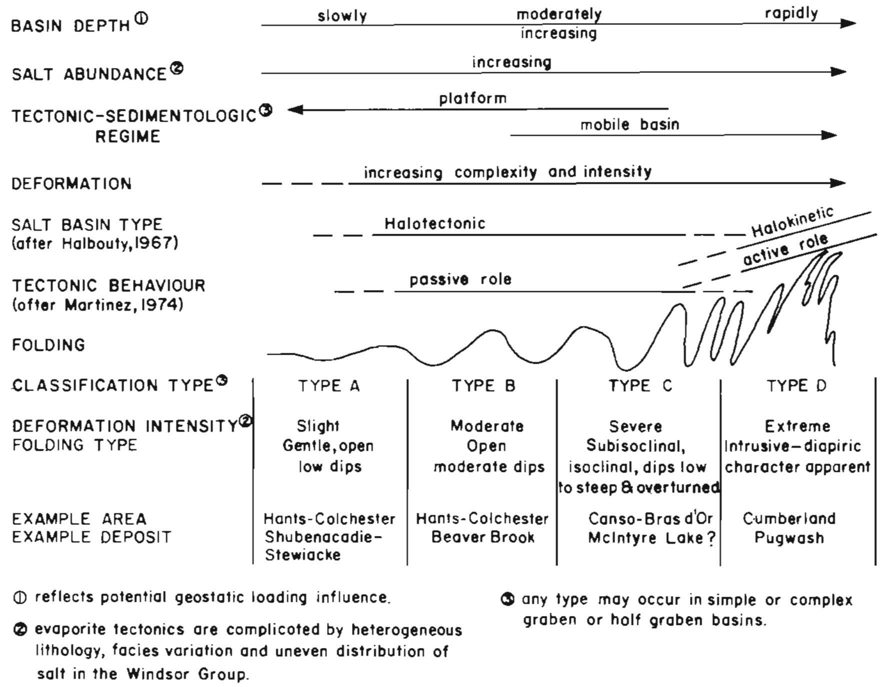

Figure 1-11. Summary of evaporite deposit classification in Nova Scotia.

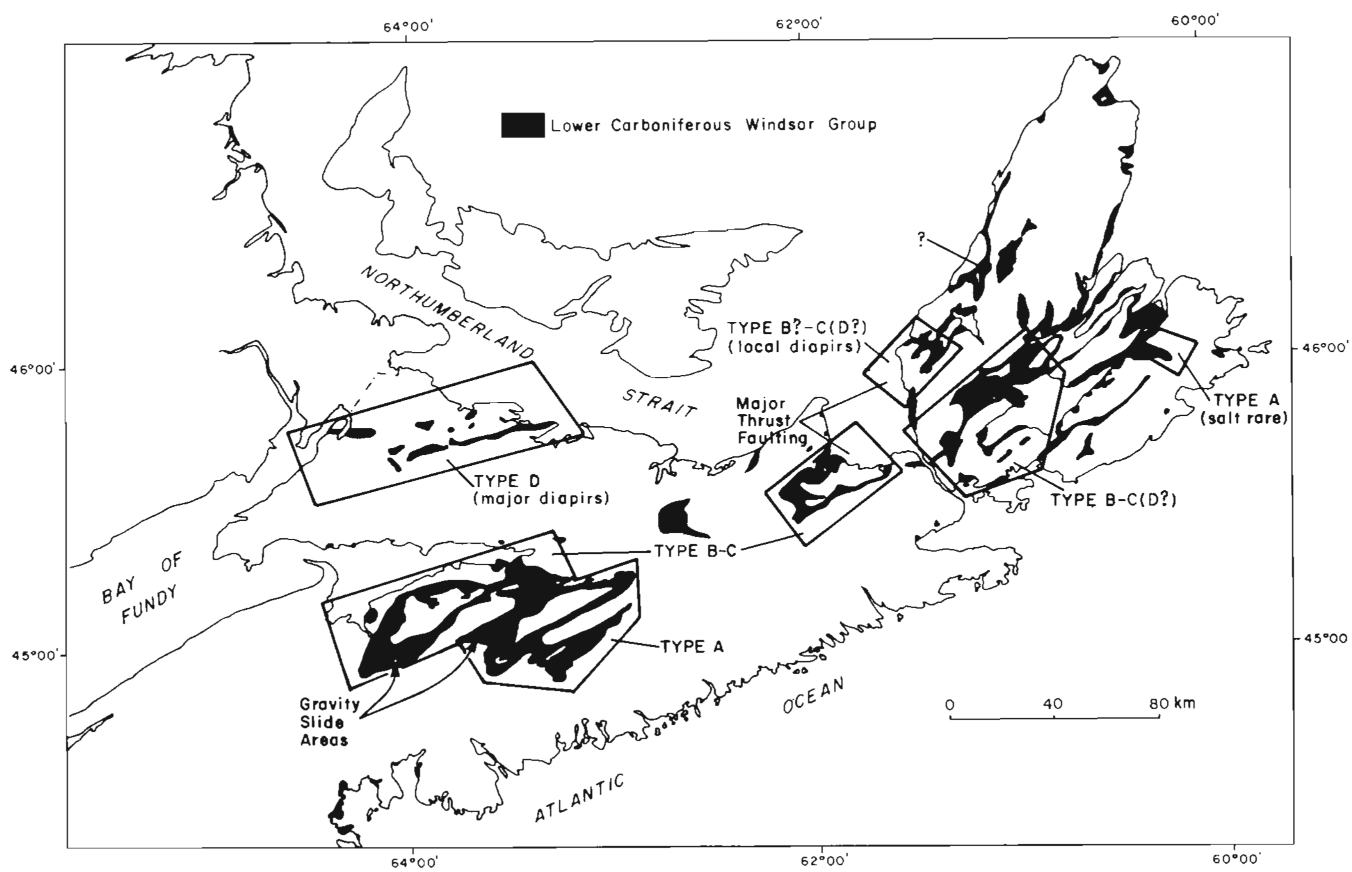

Figure 1-12. Distribution of salt deposit structural types in Nova Scotia (see Fig. 1-11 for explanation of salt deposit structural types).

the Bras d'Or area in central Cape Breton (Types B and C). In these areas the Windsor Group salt occurs in variably faulted synclinoria where thickening of the evaporites is generally minor. Thickening where present appears to be limited to local "welts" in anticlinal or synclinal cores or as fault bounded synclinoria between basement blocks. A major thrust fault is inferred to occur at the top of Major Cycle 1 in the Antigonish Basin (Boehner and Giles, 1982). This fault, which may be related to major strike slip faulting, is suspected to occur in other areas including Mabou in western Cape Breton Island. Slightly deformed, stratified salt (Type A) is not common in Nova Scotia although in the eastern part of the Hants-Colchester area (Shubenacadie-Stewiacke deposit) there is a major deposit of relatively undisturbed salt. This area of relatively thin sedimentary cover was probably subject to less intense deformation because it is outside the mobile central belt of the Magdalen Basin. Large and small scale recumbent fold structures with multiple repetition of stratigraphic units have been described locally in parts of the Hants-Colchester area (Figs. 1-4, 1-10, 1-11) by Giles (1977), Boehner (1977c) and Geldsetzer et al. (1980). This folding is inferred to have been related to tectonic uplift, detachment and gravity sliding on the top of Major Cycle 1 evaporites (especially the salt).

SALT DISSOLUTION FEATURES

Cap rock development of the Gulf Coast type is not known to occur in association with the Windsor Group in Nova Scotia. Residual collapse breccia is common in areas where saline Windsor Group comes to the surface. The residual breccia is well developed at Pugwash and Nappan where blocks of gypsum and carbonate resistates are found in poorly to unconsolidated mud forming an irregular cap to the evaporite diapirs. Giles (1981a) described telescoped collapse brecciated sections of highly deformed saline Windsor Group in the McIntyre Lake area of Cape Breton Island. In this area, halite has been preferentially dissolved to a depth of 200-300 m leaving the original stratigraphic succession intact but thinned with the relatively insoluble brecciated anhydrite-gypsum and carbonate infiltrated by mudstone. A similar situation was described in the Malagawatch area by Dekker (1982a, b). Salt removal, residual accumulation and collapse brecciation may be expected in the vicinity of faults, permeable strata and in areas where the Windsor Group outcrops. The absence of salt springs and seeps in many areas of these features indicates salt dissolution has been reduced or halted, possibly by the sealing action of residual clay and mud. The widespread occurrences of salt springs, seeps, and saline formation water indicate that the salt areas are not completely sealed.

HISTORY OF POTASH EXPLORATION IN NOVA SCOTIA

INTRODUCTION

Exploration activity for potash in Nova Scotia reached an all time high following reports of a potash occurrence in a borehole on the Chevron Standard-Irving Oil Ltd. property near Malagawatch, Cape Breton Island (Dekker, 1982a,b; Fig. 1-4). Exploration was further encouraged by the discovery of ore grade potash in the Windsor Group evaporites of New Brunswick in the early 1970's. Two deposits are under development in New Brunswick: one near Sussex by the Potash Company of America (Fig. 1-4) and the other near Salt Springs by Denison Mines (after International Minerals and Chemical Corporation (Canada) Ltd). Although these are the first two economic deposits to be developed in southeastern Canada, the presence of potash was recorded shortly after the turn of the century.

EARLY WORK

The first confirmation of potash mineralization associated with salt in Nova Scotia was made in the early workings of the Malagash Mine in 1919 (Hayes, 1920). Although the grade and extent of the potash was later discovered to be limited and subeconomic, the possibility of finding economic deposits in other areas could not be overlooked.

Hayes (1920) described the geology of the Malagash Mine area and reported that the potash encountered in the upper mine workings occurred as a lenticular deposit of pink and yellow-green sylvite in a matrix of halite. The thickness and grade were highly variable, generally less than 1.5 m thick and less than 10 per cent potash. Ellsworth (1926) described the chemistry of the potash horizon in the upper levels of the Malagash Mine and reported that the sylvite lenses were associated with red coloured salt (hematitic) and that magnesium salts were virtually absent. Messervey (1950) reported that drilling and crosscutting at lower levels in the Malagash Mine yielded a proven tonnage of 80 000 tons at 8 per cent KCl with an additional 145 000 tons reasonably assured.

Potash is also present in the Nappan area (Fig. 1-4). Roliff (1932) reported that several samples of salt cuttings from the Amherst No. 1 oil well drilled by Imperial Oil Ltd. contained greater than 1 per cent (calculated) KCl. Two samples from near the top of the salt section contained 4.50 and 4.42 per cent KCl (calculated). Description of this well indicated the presence of bitter and reddish salts at 982.1 m - 985.2 m (3220-3230 ft.) which corresponded to the potash in the Malagash Mines. Analyses from this section of the Amherst well indicate 1.18 per cent KCl (calculated).

The first major exploration for potash was initiated in 1930 when a regional survey was conducted by Hayes (1931) on behalf of Imperial Chemical Industries Ltd. of New York. This survey involved sample analyses of salt springs and geological mapping. Exploration drilling was not undertaken.

In the late 1950's and early 1960's systematic gravity surveys of Carboniferous outcrop areas in parts of Cumberland, Colchester, Hants and Pictou Counties were carried out by the Nova Scotia Research Foundation. Prior to these, only local gravity or seismic surveys were undertaken by petroleum exploration companies in the Malagash-Wallace and Mabou areas. These and subsequent geophysical surveys are of great assistance in assessing the presence and depth of salt in the various Windsor Group outcrop areas in the Province. Major gravity anomalies (minima) were shown to be invariably coincident with known Windsor Group outcrop suspected to contain salt. A large number of these anomalies in the Hants-Colchester and Cumberland areas were drilled to relatively shallow depths in a sulphur exploration program by Scurry Rainbow Oil Ltd. (1967). Although the company was not successful in locating sulphur or potash, minor occurrences of salt were recorded. Additional deep drilling will be required to properly evaluate the geophysical anomalies of these areas.

RECENT EXPLORATION

Exploration drilling for salt in Pugwash resulted in the opening of the Pugwash Mine in 1958 by the Canadian Salt Company. Potash salts were encountered in some of the exploration drillholes, and later in the mine, in thin discrete layers within the highly deformed salt. These potash salt layers, studied by the Nova Scotia Research Foundation (1962) and Aumento (1964), were found to occur in subeconomic grades and thicknesses typically less than 5 per cent K_2O over intervals of a few feet. The principal potassium minerals, according to Aumento (1964), were carnallite with lesser amounts of sylvite in association with halite and fine siliciclastic material.

The Nova Scotia Research Foundation (1962) indicated three distinct types of potash salt occurrences in the Pugwash Mine area. The first occurs as matrix cement with halite in breccia and clay-mudstone. The second occurs as tiny blebs in salt bands located within a few feet of a breccia zone. The third occurs as veins with red orange fibrous crystals of halite with clay. The complex isoclinal folding of Windsor Group evaporites in Pugwash Mine was described in detail by Evans (1967, 1972). He indicated the potash zones of "carnallite breccias" and sylvite occur mainly near the inferred base of the section which contains the siliciclastic-rich salt.

Baar (1966) reported the bromine content of Windsor Group salt could be used as an indicator of the degree of brine concentration of the original precipitates. Potash salt is an end product in evaporite precipitation, so the more concentrated the brine the more favourable the environment for the accumulation of potash. According to Baar, (1966) from his studies of salt deposits in Germany, when primary potash precipitation occurs the Br/NaCl ratio rises from 0.007 to 0.02.

From his studies in Nova Scotia, Baar (1966) concluded that brine concentrations may have reached primary potash mineral deposition in the lower part of the Pugwash Mine section and also in the lower most part of the salt section at Nappan (Fig. 1-4). Evidence was found in the Pugwash Mine for bromine alteration as the result of migrating solutions from a pre-existing enriched source during deformation. These migrating fluids produced secondary potash minerals within permeable hosts and their Br content was at disequilibrium with enclosing rocks. Baar (1966) further concluded that potash accumulation probably occurred in the deepest part of the Cumberland Basin. In the Antigonish-Mabou and Minas Basin areas the study did not indicate a high brine concentration.

In 1966 the Province of Nova Scotia, with funding from the Atlantic Development Board, initiated a potash exploration program in Cumberland County. Specific targets were the extensions of the potash zone found in the Malagash Salt Mine to deeper areas along the strike of the Malagash Anticline. The Wallace No. 1 and No. 2 drillholes intersected steeply dipping (55°) subeconomic grade potash salts mixed with halite, siltstone and mudstone. The maximum grade thickness was 4.1 per cent K_2O over 42.4 m (139 ft.) or 5.05 per cent K_2O over 29.9 m (98.2 ft.) at depths of up to 1200 m. Goudge (1967) suggested that because the Wallace cores were drilled using a fluid not saturated in potash (sylvite or carnallite), the analyses might be low because of incomplete recovery due to leaching.

Evans (1970c) described the genesis of the potash in the Wallace cores and reported that sylvite was the dominant potassium mineral. The sylvite occurred with halite and minor carnallite in a matrix of dense clay mudstone or with halite in a halite mudstone breccia.

A petrographic study by Evans (1970c) indicated sylvite occurred as a secondary product of leaching of carnallite with abundant halite pseudomorphs after carnallite. A replacement series of halite after sylvite after carnallite was described with talc, quartz, and hematite developed as reaction products from released Mg with siliciclastics. Evans (1970c) concluded that the original sediment was probably a carnallite and halite bearing clay. This was later elevated and brecciated during diapirism.

From 1967 until the early 1970's there was very little exploration activity for potash until trace amounts of potash were intersected in the western part of the Antigonish structural basin by Millmor-Rogers Sydicate (1974) and Amax Exploration Ltd. (1975) (Fig. 1-4). Stewart (1976) studied the core from the James River drilling and reported the presence of sylvite after carnallite in halitic mudstone in drillhole AP-1-74. A maximum value of 6.25 per cent K_2O is indicated in selected samples taken from a mineralized zone 1.3 m in length with the greatest concentration over a 10 cm section in the centre of the zone. The potash zone was concluded by Stewart (1976) to occur within the major A Subzone evaporite section at the base of the Windsor Group (Fig. 1-13).

In 1975 potash exploration drilling was conducted in the Shubenacadie area by Noranda and St. Joesph Exploration Companies. Potash was not reported, but a very large salt deposit was established.

Since the late 1960's, the Strait of Canso and central Cape Breton Island (Canso Bras d'Or area) have been sites of renewed salt exploration activity (Fig. 1-4). The most recent activity is by Chevron Canada Ltd. and Noranda Exploration Company Ltd. directed at (Dekker, 1982a,b) potash exploration in the Bras d'Or Lakes area.

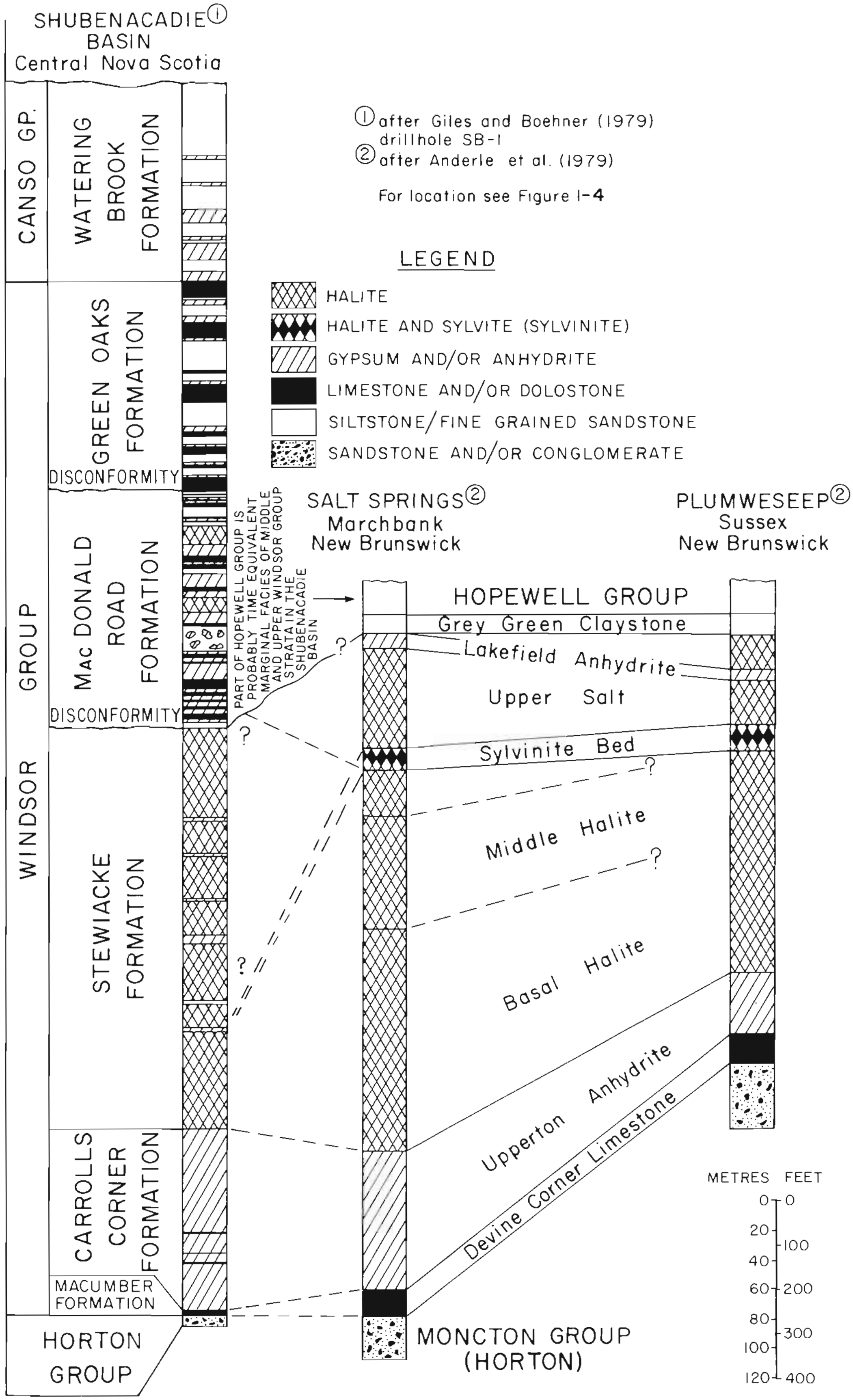

Figure 1-13. Comparative stratigraphy of selected Windsor Group evaporite basins in Nova Scotia and New Brunswick.

Interesting, but apparently subeconomic showings of potash salts have been reported in the evaporite sections drilled at McIntyre Lake (Hale, 1972; and Giles, 1981a) and also at Port Richmond. Maximum values reported are 14.11 and 13.34 per cent K_2O over intervals of 30 cm (1 ft.). Core logs of the evaporite sections in this hole commonly report the occurrence of the potash salts carnallite and sylvite. Although the grades and thicknesses are subeconomic, the occurrence of the potash salts within the interstratified halite, anhydrite, siltstone and marine limestone, typical of the middle and upper parts of the Windsor Goup (Figs. 1-8 and 1-13), may be important to further exploration concepts applied to Nova Scotia evaporite basins.

NEW BRUNSWICK OCCURRENCES

The geology of two potash deposits in Windsor Group evaporites in New Brunswick have been described by Kingston and Dickie (1979) and Anderle et al. (1979). According to Kingston and Dickie (1979), the deposits at Sussex and at Salt Springs have similar stratigraphy (Fig. 1-13) and mineralogy but slightly different tectonic histories. The potash ore zone is a sylvite-halite mixture (sylvinite) situated near the top of a thick carbonate-anhydrite-halite evaporite section that may be over 400 m thick. This major evaporite sequence is overlain by a thinner section of interstratified halite and anhydrite and then terrigenous rocks (Fig. 1-13). In the Sussex area (Figs. 1-4) the structural configuration is anticlinal (Anagance Axis) and at Salt Springs is synclinal (Marchbank Syncline). In both areas, the potash horizons display varying degrees of deformation and structural complexity. In the case of Sussex, the potash zone is apparently absent at the crest of the anticline and is postulated by Kingston and Dickie (1979) to have been removed by circulating groundwater, in a process referred to as "subrosion".

NOVA SCOTIA COMPARISONS

A clear, detailed stratigraphic correlation between Nova Scotia's evaporite basins (based upon the Shubenacadie area) and New Brunswick's evaporite basins is not possible with the available data. Similarities do exist, however, especially in the lower most parts of the sections (Fig. 1-13) where a major depositional succession of carbonate followed by halite is evident. Within the Shubenacadie Basin, for comparison, potassium salts are not present. The evaporite cycle, including potassium salts, appears to be more complete in the case of the New Brunswick sections. Windsor Group basins in which this major evaporite cycle is complete (up to potassium salt deposition) are major exploration targets. The section above the major evaporite succession is not readily correlative (Fig. 1-13). Hypothetically, the MacDonald Road and Green Oaks Formations may be represented, in whole or in part, by the upper salt and the Hopewell Group section in New Brunswick. In Nova Scotia potassium salts were deposited at higher levels in the cyclic middle and upper parts of the Windsor Group (Fig. 1-8).

Potash salts are known to be present only in Windsor Group rocks north of the Minas Geofracture (Figs. 1-1, 1-4 and 1-10, in pocket). This area is roughly coincident with the Fundy Basin (mobile rift) of Belt (1968).

In Nova Scotia it has not yet been determined if the potash was deposited in economic quantities. It is also unclear what factors were important in the localization of any deposits, i.e. in the deeper more rapidly subsiding basins and/or in paleogeographically remote basins which were physically or dynamically restricted.

Because these areas were within or close to the mobile area, they have undergone substantial deformation (Fig. 1-9). This structural complexity and scarcity of subsurface data make detailed paleogeographical-depositional modelling difficult to impossible. It is encouraging, however, that some areas, such as the Antigonish Basin, may not have been subjected to the intense evaporite flowage and deformation prevalent in other areas.

DISTRIBUTION OF SALT DEPOSITS AND OCCURRENCES

The five areas with known salt deposits (Figs. 1-4 and 1-10, in pocket) in Nova Scotia are the Hants-Colchester, Cumberland, Antigonish-Mabou, Canso-Bras d'Or and Sydney areas. In addition, four areas underlain by Windsor Group rocks may contain salt deposits, but this has not been established by drilling. These are the Mahone Bay, Pictou, Cheticamp-Margaree and Cape North areas. Thick salt deposits are found in most areas underlain by Windsor Group rocks (Figs. 1-1 and 1-5). In many of these areas, the Windsor Group rocks are overlain by a very thick sequence of Late Carboniferous rocks.

Within the five areas where salt is known to occur, 13 occurrences and 20 deposits are recognized (Fig. 1-10, in pocket and Table 1-2). Table 1-2 lists, groups, and classifies each deposit and occurrence, and assesses its potential for both salt and potash exploration. The exploration potential is based only on the limited area of the deposit or occurrence. Areas without salt defined by drilling may have significant potential, but cannot be objectively evaluated without more data.

The deposits and occurrences are sometimes defined in only a single drillhole and, as such, are inadequately known. The designation of deposit or occurrence is purely arbitrary and is based upon the quantity of salt actually intersected in drilling coupled with the quantity which may reasonably be present by comparison with similar structural and geological conditions in other better defined deposits and from gravity data where available. The deposits and occurrences were assessed only on their geological merits, with the quality of the salt, mining factors and depth to salt etc., not considered. The data related to these factors, with the exception of the depth, are generally unknown and highly variable, and therefore of limited value. The assignment of the deposit or occurrence rank is subject to further modification as the factors related to exploitability are studied in more detail and become better understood.

Between 1978 and 1980, five new deposits were defined by Noranda Exploration Company Ltd. and Chevron Standard Ltd., while they were conducting potash exploration in the Canso-Bras d'Or area. Two of these deposits, Orangedale and Malagwatch, contain associated potash. The others, Cleveland, Estmere, and St. Patricks, are defined by only one drillhole. Data on these deposits only became available following preparation of this report and will not be described here in detail.

Table 1-2. Nova Scotia salt deposits and occurrences

	Deposit or Occurrence	**Structural Type**	**Major Cycle(s)**	**Potential for Salt Exploration**	**Potential for Potash Exploration**
Hants-Colchester Area					
Beaver Brook	Deposit	B	1	good	poor-fair
Clarksville	Occurrence	B-C	5	fair	fair-good
Falmouth	Occurrence	?	1	poor	poor
Kennetcook	Occurrence	B-C	1	poor	poor
Shubenacadie-Stewiacke	Deposit	A	1,2,5	very good	poor
Stanley	Occurrence	B-C	1	fair	poor
Summerville	Occurrence	Vein	-	very poor	very poor
Upper Walton River	Occurrence	C	1-2?	poor-fair	poor-fair
Walton	Occurrence	B-C	1-2?	poor-fair	poor-fair
Cumberland Area					
Beckwith	Occurrence	C-D	?	fair	good
Malagash*	Deposit	D	?	fair	good
Nappan*	Deposit	D	?	fair	poor
Oxford*	Deposit	D	?	fair	fair-good
Pugwash*	Deposit	D	?	very good	good
Roslin	Occurrence	D	?	fair	fair
Antigonish-Mabou Area					
Antigonish	Deposit	B-C	1	fair	fair
James River*	Deposit	B-C	1	fair-good	fair-good
Mabou	Deposit	C-D	1-4?	fair-good	fair-good
Ohio	Occurrence	A	1	poor-fair	poor-fair
Pomquet River	Occurrence	C	1?	poor	poor
Southside Harbour*	Deposit	B	1	good	fair
Canso-Bras d'Or Area					
Cleveland*	Deposit	B-C	2-5?	fair	fair
Estmere	Deposit	B-C	2-5?	fair	fair
Kingsville	Deposit	C-D	1-5?	very good	fair-good
McIntyre Lake*	Deposit	C	1-5?	very good	good
Malagawatch*	Deposit	C?	1-4	good	good
Orangedale*	Deposit	C?	1-4	good	good
Port Richmond*	Deposit	C-D?	1-4	very good	fair
Seaview	Occurrence	C	1?	fair	fair
St. Patricks Channel	Deposit	C	1-4	fair-poor	fair-poor
St. Peters*	Deposit	C	1?	fair	fair
Sydney Area					
Boularderie	Deposit	A-B	1-2	good	good
East Bay	Occurrence	A	1?	fair	poor

*Potash salts reported.