IC 2008–4

CD-ROM

New Nouveau Brunswick

Natural Resources
Minerals, Policy and Planning

Information Circular

NEW BRUNSWICK POTASH:

A Review of Developments and Potential Exploration Alternatives

T.C. Webb

ISSN 1919-3297
ISBN 978-1-55396-882-5

Price: $2.00
2009

Information Circular 2008–4 (CD-ROM)

NEW BRUNSWICK POTASH:

A Review of Developments
and Potential Exploration Alternatives

Figure preparation Terry Leonard

Editing, design, layout Shasta A.A. Merlini

Recommended citation

Webb, T.C. 2009. New Brunswick Potash: A Review of Developments and Potential Exploration Alternatives. New Brunswick Department of Natural Resources; Minerals, Policy and Planning Division, Information Circular 2008–4 (CD-ROM), 21 p.

This report has been prepared by:

Minerals, Policy and Planning Division
Department of Natural Resources
New Brunswick

Hon. Wally Stiles
Minister of Natural Resources

January 2009

TABLE OF CONTENTS

ABSTRACT iii
RÉSUMÉ iv

Introduction 1
Regional Geologic Setting 2
Geology of Carboniferous Basins in New Brunswick 2
  Horton and Sussex groups 4
  Windsor and Mabou groups 4
  Cumberland and Pictou groups 6
New Brunswick Potash: Thirty-eight Years of Exploration and Development 6
  Moncton Subbasin 7
  Penobsquis-Plumweseep: discovery to production 7
    Mining, refining and waste management practices: PCS Potash (New Brunswick Division) 8
  Clover Hill-Salt Springs: discovery to production 10
    Mining, milling and waste management practices: the former Potacan Mining Company 12
  Cocagne Subbasin 13
  Millstream: discovery and exploration 13
Possible Additional Potash Resource Potential in New Brunswick 14
  Moncton Subbasin 15
  Cocagne Subbasin 15
  Sackville and Cumberland Subbasins 16
  New Brunswick Platform 16
Conclusions 18
Selected References 19

LIST OF FIGURES

Figure 1. Stratigraphic columns of Middle to Late Devonian to Late Carboniferous rock formations of the Maritimes Basin in southern New Brunswick, Canada displaying major stratigraphic horizons containing known potash deposits and related Windsor Group evaporites 3

Figure 2. Potash potential: New Brunswick Carboniferous subbasins and potential areas of interest with regard to potash and gravity features indicating the possibility of subsurface Windsor Group evaporites. 5

NOTES

ABSTRACT

Recent developments affecting the demand and supply of potash to global agricultural markets has resulted in an extraordinary level of interest in this strategic mineral resource. Record-breaking demand for this key ingredient to most fertilizers has prompted expansions to production capacities among established potash producers throughout North America and elsewhere. This situation has also attracted interest among the exploration and development community, the like of which has not been seen in Canada's potash sector in half a century.

In parts of Atlantic Canada potash mineralization is found associated with Early Carboniferous, marine evaporite deposits of the Windsor Group. In south–central and southeastern New Brunswick, five Carboniferous subbasins can be considered as potential areas of interest for subsurface Windsor evaporites. The Moncton and Cocagne subbasins are associated with confirmed potash deposits that have a history of development and unqualified potential for additional exploration. The Sackville and Cumberland subbasins are known to contain Windsor evaporites, however with a few exceptions, the nature of these deposits and the presence of potash mineralization has yet to be verified. In a fifth area, exposures of Windsor rocks occur sporadically along the southern border of the New Brunswick Platform but the presence of evaporites remains unconfirmed.

In most parts of south–central and southeastern New Brunswick, expectations of additional potash deposits must be considered speculative at this point based on the current geotechnical information. More detailed investigation is clearly required to properly assess the region's potential.

RÉSUMÉ

Les développements récents affectant l'offre et la demande de potasse au sein des marchés agricoles mondiaux ont entraîné un niveau d'intérêt extraordinaire à l'égard de cette ressource minérale stratégique. La demande record de cet ingrédient clé de la majorité des engrais a engendré des expansions des capacités de production des producteurs de potasse établis partout en Amérique du Nord et ailleurs. Cette situation a également suscité dans le milieu de l'exploration et de la mise en valeur un intérêt d'une ampleur jamais vue au sein du secteur de la potasse du Canada en l'espace d'un demi-siècle.

Les minéralisations de potasse présentes dans certaines régions des provinces de l'Atlantique sont associées à des dépôts évaporitiques d'origine marine du Carbonifère précoce du groupe de Windsor. Dans le Centre–Sud et le Sud–Est du Nouveau-Brunswick, cinq sous-bassins du Carbonifère peuvent être considérés comme des secteurs d'intérêt éventuels en ce qui concerne les évaporites souterraines du groupe de Windsor*. Les sous-bassins de Moncton et de Cocagne sont associés à des gîtes de potasse confirmés ayant déjà fait l'objet par le passé de mise en valeur et présentant un excellent potentiel en vue d'une exploration supplémentaire. On n'a pas encore vérifié l'étendue et la nature de la minéralisation de la potasse dans la majorité des secteurs des sous-bassins de Sackville et de Cumberland. Des affleurements de roches du groupe de Windsor se manifestent le long de la limite méridionale de la plate-forme du Nouveau-Brunswick, mais il reste à déterminer si des évaporites sont présentes.*

Dans la majorité des régions du Centre–Sud et du Sud–Est du Nouveau-Brunswick, il faut considérer pour le moment les attentes par rapport aux gîtes de potasse supplémentaires comme des hypothèses basées sur les données géotechniques courantes. Il faudra des études plus poussées pour évaluer adéquatement le potentiel de la région

NEW BRUNSWICK POTASH:
A REVIEW OF DEVELOPMENTS AND POTENTIAL EXPLORATION ALTERNATIVES

Introduction

For nearly 80 years, North America's potash industry has been rooted in the southwestern US state of New Mexico, near Carlsbad and the southern part of the western Canadian Province of Saskatchewan. Thirteen potash mining and processing facilities in these areas account for a majority of the continents potash production capacity, with the remainder derived from an operation in the eastern Canadian province of New Brunswick and from two operations in the respective north–central and western US states of Michigan and Utah.

The world potash market has been experiencing rapid growth over the last decade. Several factors are contributing to an increased demand for potash, a key component of most fertilizer blends. Higher rates of consumption of various agricultural products (i.e., food, fiber and feed) and a burgeoning bio-fuels industry are among some of the primary market drivers. As a result, the global gap between supply and demand for potash has narrowed significantly in recent years. This trend is reflected in higher operating levels and utilization of idle production capacity by current potash producers and upward pressure on global potash prices. Recently, it has been reported that contract negotiations between China and Canadian potash producers have resulted in price increases exceeding 300% (Partridge and Hoffman 2008). Other similar increases in contract and spot prices to Southeast Asia, Brazil, and India (O'Driscoll 2008; Industrial Minerals 2008) further demonstrate the large imbalance in potash supply/demand. With increasing concerns over global food production, continued upward pressure on potash demand appears to be a reality into the near future.

This situation has triggered production expansion projects at several Canadian mines and it has influenced Potash Corporation of Saskatchewan Inc.'s decision to construct a new, two-million-tonne/year (mt/yr) potash mine and processing facility near its present operation in New Brunswick. This New Brunswick project is projected to cost of near $Cdn 1.7 billion and represents the first new potash mining operation constructed in Canada in almost a quarter of a century. Renewed interest in green-field potash exploration and development in several Canadian Provinces, the likes of which has not been seen in almost 50 years continues to attract new players and investors to the industry.

Indications of potash mineralization were known from various parts of Canada's east coast (Atlantic Canada) for many years. The discovery and subsequent development of relatively thick and good grade potash ore in parts of southeastern New Brunswick beginning in the early 1970s has resulted in the establishment of two world class mining operations, development of a third deposit and partial definition of a fourth deposit.

Throughout Atlantic Canada, potash mineralization of economic significance is restricted to Early Carboniferous marine evaporite deposits of the Windsor Group. In New Brunswick, extensive areas with undefined potential for Windsor Group evaporites in the subsurface remain unexplored. Generally, potash resources in New Brunswick and other parts of Atlantic Canada can be expected to present various structural complexities compared to those in western Canada and New Mexico. In some cases however, this can actually be a positive attribute, resulting in a structural thickening of an ore zone(s), thereby improving resource recovery. The regions maritime location, with most potential exploration targets situated a few hundred kilometres from tidewater and established port facilities, offers a definite logistical advantage in servicing a rapidly expanding global potash demand.

Regional Geologic Setting

Salt and associated potash deposits in the Atlantic Canada region occur in Early Carboniferous (Viséan) rocks of the Windsor Group, which forms part of the Late Devonian to Early Permian Maritimes Basin. This successor basin, elements of which are described by St. Peter (1993 and 2006), developed over an area of nearly 75 000 km^2 in the wake of a series continental collision events terminating with the formation of the Appalachain Mountain chain.

As tectonism waned, Late Neoproterozoic to Early Proterozoic basement of the Appalachain system subsided, forming a complex series of northeasterly trending horst and graben structures, precursors of important depositional troughs and intermontane basins. These features evolved into important depocentres for a host of alluvial, fluvial, lacustrine and locally, volcanic sequences, and for the evaporite deposits considered here.

Several episodes of faulting and folding have affected the strata of the Maritimes Basin (St. Peter 2006). In and near deformed regions, evaporites are complexly folded into isolated diapiric structures, salt ridges or walls. Away from zones of deformation, deposits are anticipated to be relatively flat lying.

Geology of Carboniferous Basins in New Brunswick

Carboniferous rocks in New Brunswick can be broadly subdivided into five major lithostratigraphic assemblages: 1) Late Devonian to Early Carboniferous (Lower Tournaisian) fine- to coarse-grained sedimentary clastics including oil-bearing sandstones and shales, of the Horton Group, including sulphate in the form of glauberite and chloride; 2) Early Carboniferous (Upper Tournaisian) coarse- and fine-grained sedimentary clastics, carbonates and evaporites of the Sussex Group; 3) Early Carboniferous (Middle to Upper Viséan) coarse-grained sedimentary clastics, carbonates, sulphates and chlorides of the Windsor and Mabou groups; 4) Late Carboniferous (Namurian to Westphalian) coarse- to fine-grained sedimentary clastics of the Cumberland Group and 5) Late Carboniferous–Early Permian (Westphalian to Asselian) coarse- to fine-grained sedimentary clastics of the Pictou Group. Although much has been published, the classic work of Gussow (1953) and more recently, that of St. Peter (1993 and 2006), provide a fairly comprehensive introduction to New Brunswick's Carboniferous stratigraphy and structure. The regional relationships between major Carboniferous stratigraphic units are outlined in Figure 1. The following descriptions are adapted in part from St. Peter (2006). For additional information pertaining to the regional distribution and nature of Carboniferous rocks in New Brunswick the reader is referred to the bedrock geology map of the province (New Brunswick Department of Natural Resources 2000), the bedrock geology maps of southeastern and southwestern New Brunswick (Smith 2006a, b) and for detailed descriptions of Carboniferous formations, the Bedrock Lexicon Database of New Brunswick (New Brunswick Department of Natural Resources 2008).

.

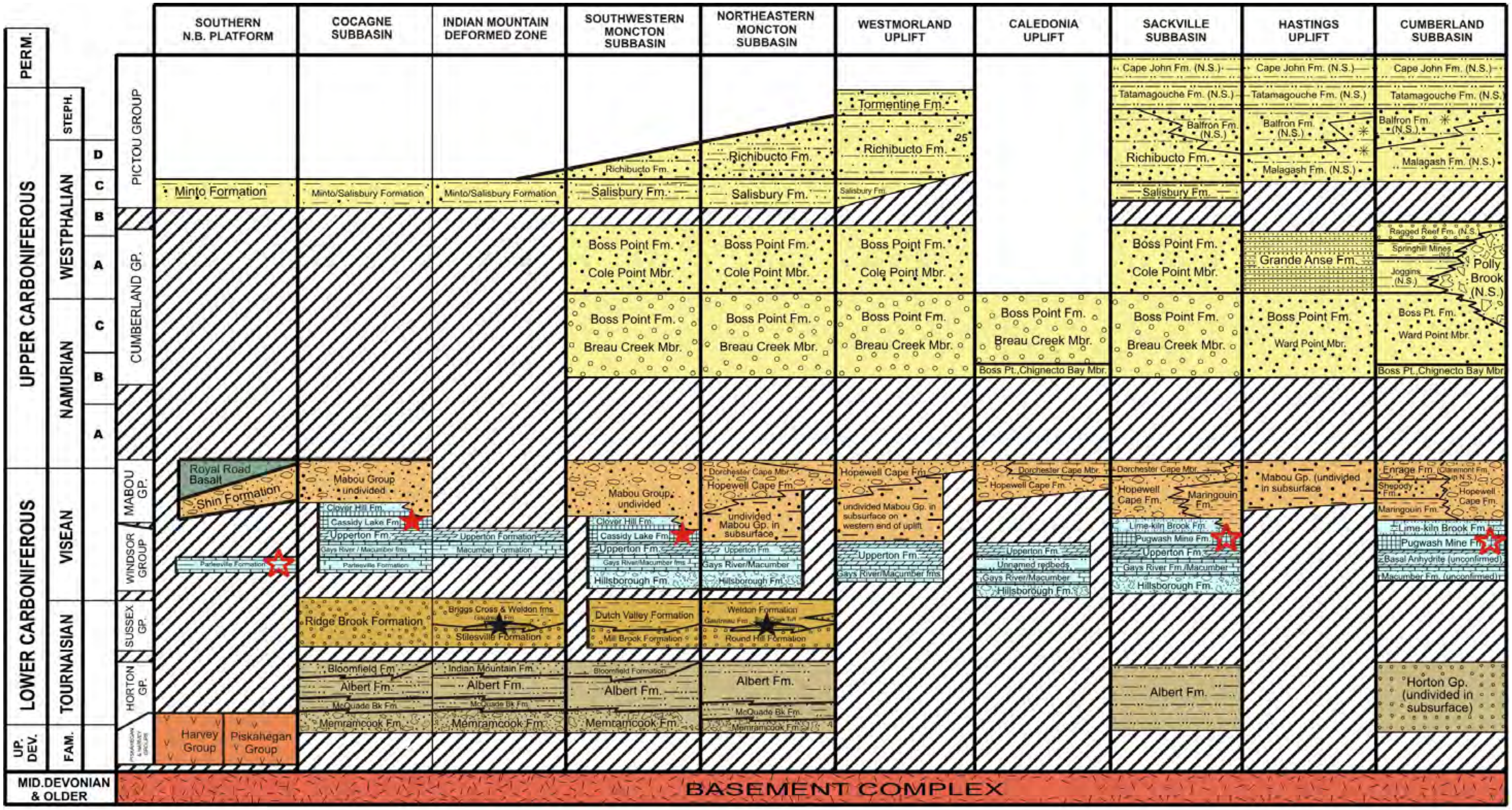


Table of Late Devonian to Carboniferous formations of the Maritimes Basin in southern New Brunswick showing stratigraphic horizons containing potash and related Windsor evaporites. Most units dated with palynological assemblages; diagonally ruled lines represent angular unconformities, disconformities or paraconformities; (NS) indicates the formation exists only in Nova Scotia. After St.Peter & Johnson, in prep; St. Peter (2006).

Marine evaporite deposits
★ potash
☆ possible potash?

Continental evaporite deposits
★ no potash

Figure 1. Potash potential: New Brunswick Carboniferous subbasins and potential areas of interest with regard to potash and gravity features indicating the possibility of subsurface Windsor Group evaporites. For additional information pertaining to the regional distribution and nature of Carboniferous rocks in New Brunswick refer to New Brunswick bedrock geology maps: NR-1 (New Brunswick Department of Natural Resources 2000), NR-5 and -6 (Smith 2006a, b) and the Bedrock Lexicon of New Brunswick (New Brunswick Department of Natural Resources 2009).

Horton and Sussex groups

The Late Devonian to Early Carboniferous Horton Group comprises the base of the basin succession and is represented by coarse- to fine-grained sedimentary clastics including important dark coloured bituminous shales and hydrocarbon enriched sandstones. Rocks belonging to the Early Carboniferous Sussex Group unconformably overlie Horton Group strata. Although Sussex Group strata are mostly comprised of continental sedimentary clastics; they also locally contain carbonate and impure deposits of glauberite (Webb 1977) and salt associated with the Gautreau Formation. Potash minerals have not as yet been identified in the Gautreau. Given the flluviatile and fluviolacustrine depositional environment proposed for such deposits (St. Peter 2006) it is unlikely potash mineralization would be associated with such strata.

Windsor and Mabou groups

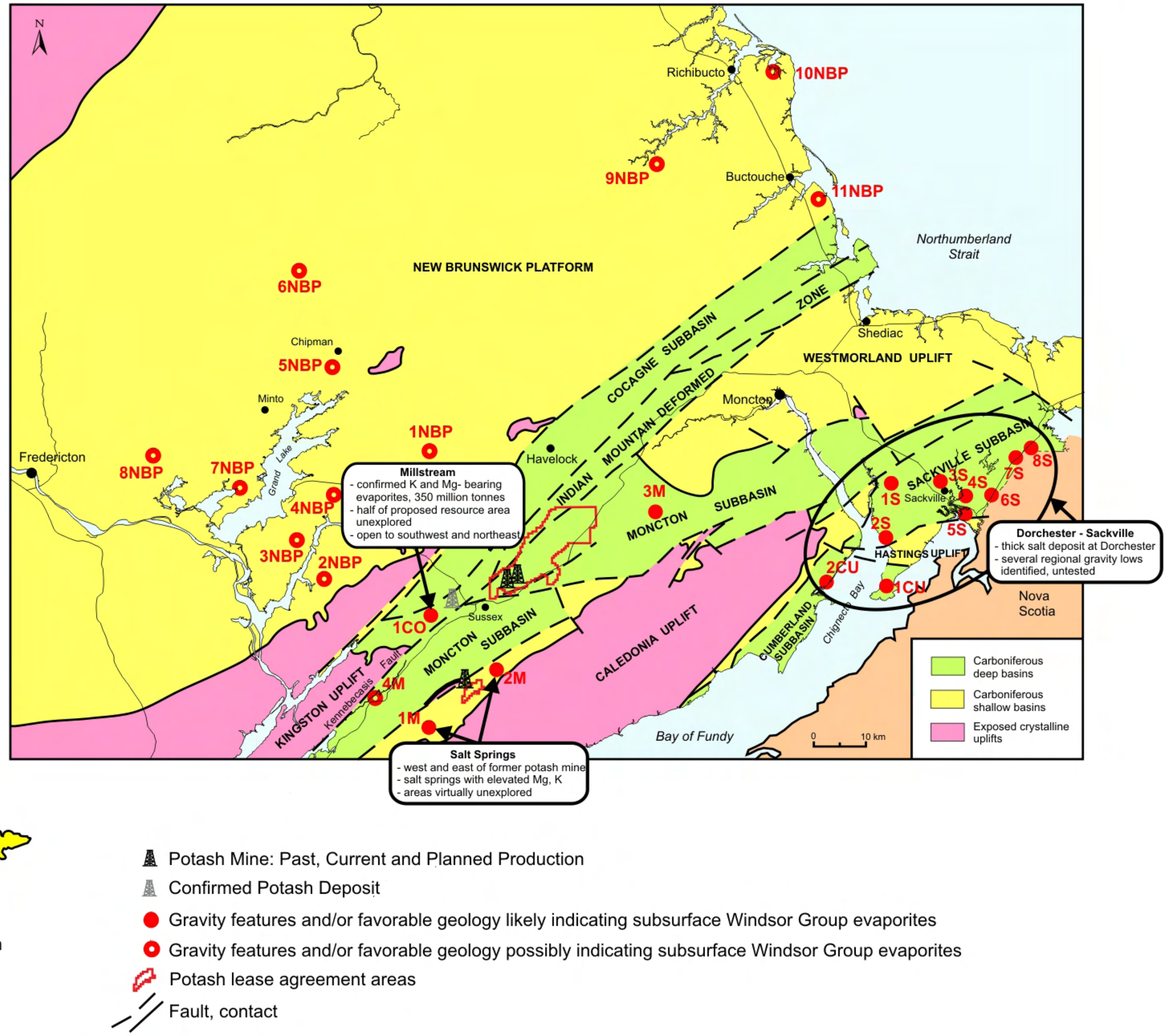
A sequence of Viséan coarse- to fine-grained sedimentary clastics, carbonates, and evaporites several hundreds of metres thick, termed the Windsor Group (St. Peter 2006), has been identified by mapping, various geophysical surveys and subsurface drilling throughout southeastern New Brunswick. In New Brunswick, the only marine sediments in the entire onshore portion of the Maritimes Basin are contained in the Windsor Group. The contact of the Windsor Group with underlying Sussex Group and basement varies from disconformable to unconformable depending on basin geometries. In New Brunswick, contact with overlying fine- to coarse-grained sedimentary clastics of the Mabou Group varies locally from gradational to erosional. The Windsor Group has attracted considerable interest over the years. Among the thickest and most widespread evaporite deposits in eastern North America, they have a long history of exploration and development and are currently mined for potash, salt, gypsum/anhydrite and limestone. Thick and extensive resources of relatively clean salt continue to attract interest as potential sites for the storage of various liquid hydrocarbon products.

Throughout Atlantic Canada Windsor Group evaporites, including sulphate and various salts, are commonly preserved in parts of several northeast- and east-trending fault-bound depocentres or subbasins, separated from each other by intervening horsts and uplifted terrane of older Carboniferous or basement rocks. In southeastern New Brunswick, these depocentres are the Cumberland, Sackville, Moncton, and Cocagne subbasins (Figure 2). Thinner or condensed accumulations of Windsor Group strata lie adjacent to these subbasin structures on the margins of regional uplifts like the Caledonian, Westmorland, and Hastings uplifts, the Indian Mountain Deformed Zone and parts of the New Brunswick Platform.

In southeastern New Brunswick, the Windsor Group is divided into several formations: basal sedimentary clastic rocks of the Hillsborough Formation; overlying near shore, to platformal to basinal carbonates of the laterally equivalent Parleeville, Gays River and Macumber formations; succeeding sulphates of the Upperton Formation; chlorides, locally accompanied by potash mineralization of the Cassidy Lake Formation, capped by chloride, sulphate and carbonate of the Clover Hill Formation in the Cocagne and Moncton subbasins; and equivalent Pugwash Mine Formation, capped by the Limekiln Brook Formation in the Sackville and Cumberland subbasins.

The thickness, lithofacies, and extent of Windsor Group strata vary considerably reflecting diversity in the structural evolution of each subbasin and post depositional

Subbasin (depocenter)	Figure 2 location	Area name
Moncton (M)	1M	Salt Springs-Smithtown-Salina
	2M	Poodiac-Jeffries Corner-Hammondvale-Markamville
	3M	Petitcodiac-Pollett River-The Glades
	4M	Hampton-Norton
Cocagne (CO)	1CO	Lower Millstream
Sackville (S)	1S	Dorchester-Coppermine Hill
	2S	Johnson Creek
	3S	Morice Lake
	4S	Sackville
	5S	Aulac
	6S	Pointe de Bute
	7S	Jolicure Lakes
	8S	Baie Vert-Uniacke Hill
Cumberland (CU)	1CU	Cape Maringouin
	2 CU	Shepody
New Brunswick Platform (NBP)	1 NBP	Cannan Rapids
	2 NBP	Mill Brook
	3 NBP	Cambridge Narrows
	4 NBP	Coles Island
	5 NBP	Chipman
	6 NBP	Upper Gaspereau
	7 NBP	Maquapit Lake
	8 NBP	Noonan
	9 NBP	Harcourt-Adamsville
	10 NBP	Richibucto
	11 NBP	Buctouche



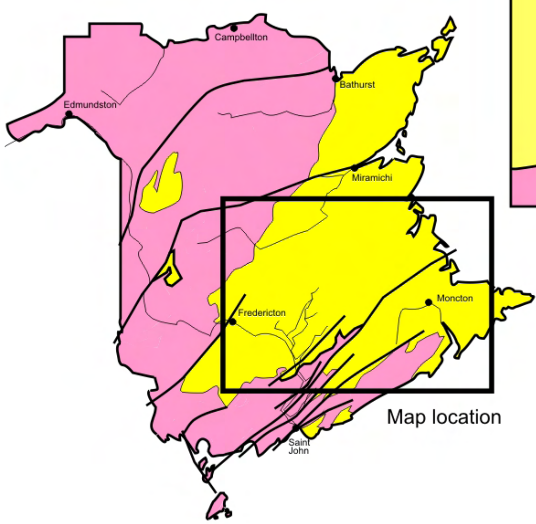


Figure 2. Potash potential: New Brunswick Carboniferous subbasins and potential areas of interest with regard to potash and gravity features indicating the possibility of subsurface Windsor Group evaporites. For additional information pertaining to the regional distribution and nature of Carboniferous rocks in New Brunswick refer to New Brunswick bedrock geology maps: NR-1 (New Brunswick Department of Natural Resources 2000), NR-5 and -6 (Smith 2006) and the Bedrock Lexicon of New Brunswick (New Brunswick Department of Natural Resources 2009).

deformation that affected Carboniferous strata throughout Atlantic Canada. As a result, the original uniform distribution of the Windsor Group has undergone significant modification.

Structurally Windsor Group strata are characterized by very limited compressive strength and structural competence and the evaporites, including salt, were particularly susceptible to deformation. Salt layers typically reacted to deformation by being squeezed out of its original site of deposition analogous to squeezing toothpaste out of its tubular container. This process, combined with salt's lower density and strong buoyancy compared to surrounding sedimentary rocks, often resulted in highly mobile, semi-fluid salt masses. Such masses have preferentially moved upwards through overlying sedimentary strata to an equilibrium position forming salt domes, thickened lenses, diapirs, salt cored anticlines, ridges, and walls. As a result, the subsurface distribution of Windsor Group salt represents the scattered structural remnants of former layered deposits that can often be located and traced by gravity and seismic geophysical methods.

Coarse- to fine-grained sedimentary clastics of the Viséan to Early Namurian Mabou Group conformably and unconformably lie above Windsor Group strata and unconformably below the sedimentary rocks of the Late Carboniferous Cumberland and Pictou groups. The thickness of Mabou Group is quite variable in southern New Brunswick, ranging up to a few thousand metres in the Sackville and Cumberland subbasins; up to a thousand metres in the Moncton Subbasin to a few or tens of metres on the New Brunswick Platform. Typically the group is a coarsening upward succession of red brown mudstone to sandstone capped by conglomerate.

Cumberland and Pictou groups

Grey to green, coarse- to fine-grained, terrestrial sedimentary clastic rocks of the Late Namurian to Early Permian Cumberland and Pictou groups overlying younger Carboniferous strata are widespread throughout New Brunswick, occupying almost a third of the Province's land mass. Variation in thickness of these rocks is related to tectonic episodes that marked the end of Carboniferous deposition in Atlantic Canada. Late Carboniferous strata in parts of southeastern New Brunswick may exceed thicknesses of two kilometres. On the New Brunswick Platform, it provides a comparatively thinner cover seldom exceeding a kilometre in thickness. Pictou rocks are known for their associated deposits of coal in the New Glasgow and Sydney areas of northeastern Nova Scotia and in the Chipman–Minto areas in south–central New Brunswick.

New Brunswick Potash: Thirty-eight years of exploration and development

Regional geological mapping and gravimetric and seismic surveys indicate five main areas with potash potential in New Brunswick. These include: the Moncton, Cocagne, Sackville, and Cumberland subbasins, and the southern part of the New Brunswick Platform (Figure 2). To date actual potash deposits are only known to occur in the western half of the Moncton and Cocagne subbasins. The Moncton Subbasin continues to be the site of major potash development in New Brunswick with deposits having been brought into production and a third deposit to achieve full production status by 2011. Exploration in the southwestern part of the Cocagne Subbasin has revealed another significant potassium (and magnesium) resource but it has yet to be developed. The existence of known deposits, presence of gravity lows in favourable geologic settings augmented by supportive seismic and geochemical data, suggest other areas in New Brunswick may have untested potash resource potential.

Moncton Subbasin

The Moncton Subbasin comprising an area of roughly 3600 km^2 extending from Saint John to Moncton is regionally bounded to the north, south and west by Early Paleozoic and Neoproterozoic rocks, and contains thick sequences of the Windsor Group including evaporites. These occur in two distinct intrabasinal, fault-bound troughs in the western half of the subbasin near Sussex – one referred to here as the Penobsquis–Plumweseep evaporite structure and the other called the Clover Hill–Salt Springs evaporite structure.

Penobsquis–Plumweseep: discovery to production

The Penobsquis–Plumweseep evaporite structure sometimes referred to as the Penobsquis “salt” ridge (St. Peter 2006) extends from Sussex northeast to the Pollett River–Petitcodiac area, a distance of approximately 40 km. The subsurface geology of this potash-bearing Windsor Group evaporite deposit has been described in several papers with that of Wilson and White (2006) providing an adequate summary. In general, the Penobsquis salt ridge comprises a salt-cored anticline up to several hundred metres thick. The upper part of the structure contains a zone of potash ore (sylvinite) of variable structural complexity, thickness and grade.

Following its discovery by a government-sponsored drilling program in 1971, exploration and development rights to the Penobsquis–Plumweseep evaporite structure were awarded through a competitive bidding process to the Potash Company of America (PCA) a division of US-based, Ideal Basic Industries, in 1973. Over the next three years, 34 holes were drilled over 4.5 km^2 at a cost near $20 000 000. This initial exploration program resulted in the signing of a mining lease agreement with the New Brunswick Government in 1977 covering 191 km^2. PCA invested $106 000 000 on the way to establishing New Brunswick’s first potash mining and milling facility on a site 6 km west of Sussex. A facility with an annual initial productive capacity of 635 000 t of potash product was envisaged. About 500 people were involved during the construction phase with the potential for 250 permanent employees pending the outcome of shaft sinking and subsequent underground development. In 1980, following satisfactory results, PCA officials announced the company would advance the project to commercial production. It would proceed immediately with the construction of a second production shaft along with a potash ore refinery and related surface infrastructure at a cost of $135 000 000 with production scheduled for 1983. After only two years of production PCA sold the facility to Rio Algom. Subsequently, in 1993, the mine was purchased by the Potash Corporation of Saskatchewan Inc. and now operates under the name of PCS Potash (New Brunswick Division), abbreviated herein as PCS (NB). Since production began in 1983, over 47 000 000 t of potash ore and over 13 000 000 t of salt have been mined from the Penobsquis–Plumweseep deposit. The ore zone, situated between 400 and 760 m below surface, varies in thickness from 7 to 61 m and has an average insitu grade of 25.84 % K_20 (Hogan 2006). PCS (NB) is a conventional mining operation and estimates its potash ore reserve on the basis of exploration drill-hole data, seismic data, definition drilling underground and actual mining results. Recoverable reserves of 71 000 000 t with an average grade of 25.6 % K_2O are reported and considered sufficient to support production at current rates for 30 years (Potash Corporation of Saskatchewan Inc. 2007b).

Potash production at PCS (NB) accounts for near 6% of parent PCS Inc.’s total annual capacity of 10 700 000 t. Over the last decade annual production of potash and salt at the New Brunswick operation has averaged 731 000 t while salt production has ranged between 590 000 and 600 000 t. The mine and mill facility has 326 active employees.

Mining, refining and waste management practices: PCS Potash (New Brunswick Division)

Mining procedures adopted at PCS (NB) are described as conventional cut and fill stopes in potash zone and room and pillar in salt areas, with zero discharge. This approach reflects the geological complexities of the deposit and the practice of disposing waste rock (tailings) from the potash milling process to the underground where it is used as backfill. The practice serves two functions: (1) it increases mine stability and (2) it allows for tailings storage in an underground setting instead of huge waste piles on surface.

The generally steeply dipping nature of the potash ore zone together with its variable strike and thickness dictate a flexible mining method to expedite efficient recovery of the resource. The potash and salt deposits are reached through two 4.93 m diameter, 616 to 637 m, vertical shafts; one serving the ore hoisting requirements from the mining operations and the other for the movement of personnel, equipment and supplies and tailings to the mine; and excess brine generated from tailings dewatering and a controlled water inflow (Hogan 2006).

During the mining operation potash is recovered using an overhand cut and fill method. This involves mining the potash ore body longitudinally from elongated rooms or stopes following the trend of the ore body at various levels with continuous mining machines. A typical potash stope can approach a strike length of 914 m. Tailings from the on-surface milling process are utilized to backfill mined-out areas behind the excavation machinery and establishing a substrate for the machinery on its return cut in the opposite direction when the end of the stope is reached. As the track mounted machine inches forward along the working face its boom mounted, rotating cutting head can be raised, lowered, and moved from side to side creating a cavern-like stope up to 6.7 m high and varying from 24 to 61 m wide. Broken potash ore from the cut face is simultaneously gathered by mechanical arms onto a network of conveyors, transporting it to the production shaft where it is hoisted to the surface in self-dumping buckets or skips with a 20 to 25 t capacity. A typical mining machine is capable of excavating up to 6900 t of ore daily. PCS (NB) utilizes several Voest Alpine AM100 Mining Machines and a PCA Mining Machine for potash stoping and related development work (Hogan 2006).

As part of its integrated mining plan salt is also mined at PCS (NB) and is an important part of operations for waste management practices (Roulston 1995). Most of the mined salt is crushed and screened and marketed as road de-icing material. The mine’s current salt production capacity is established at 800 000 t/y, however actual production seldom exceeds 600 000 t/y. Salt stopes are usually mined in pairs, transverse to the dip of the potash ore body, by way of a room and pillar mining method. Stopes vary in length from 305 to 457 m, and are typically 21.3 m wide and 21.3 m high with 50 m pillars left between (Hogan 2006). Mined salt is crushed and sized underground with marketable product hoisted to surface and undersized material conveyed to a potash production stope as backfill.

Approximately two tonnes of potash ore are mined for every tonne of potash product (Roulston 1995). In an operation with an annual product production capacity of 785 000 t there is the potential to create 1 570 000 t of waste material. The potash refining process and salt and potash mining operations generate three main waste streams: salt, slime, and brine that must be managed in an environmentally acceptable manner. Since New Brunswick’s maritime climate does not permit for such materials to be stored on surface, fine salt tailings from the refining process and rock salt crushing and screening operation are sent directly to active potash mining stopes and used as backfill. Insolubles (slimes) and excess brine generated are piped as slurry to one of several basin shaped stopes created during the mining of salt. After the insolubles in the slurry settle out the clarified brine is withdrawn to an adjacent stope and subsequently pumped back to surface. This brine serves as feedstock for an evaporation process, where the contained potash is recovered, compacted and crushed for product. The fine salt generated during the process is added to the solid tailings stream for mine backfill.

Excess brine is not only dealt with from the refining process. Mine officials have been dealing with brine generated from an inflow into the underground workings since 1998. Underground drilling and grouting operations have been underway for sometime as a mitigative control measure. In 2007, increasing inflow rates prompted the implementation of an enhanced drill/grout program from surface into a fracture zone encountered above the salt structure at 389 m. Late in the fall it was reported that inflow had stabilized. Brine from the inflow is collected and pumped to surface. Over 300 tanker truck loads of brine leave the mine site daily for the 38 km haul to PCS Inc.'s Cassidy Lake Division where it is conveyed to a 35 km pipeline for disposal in the Bay of Fundy. Brine is also transported 70 km to the potash terminal in Saint John for disposal in the Bay when required. Company officials report (Potash Corporation of Saskatchewan Inc. 2007a) that mitigation costs associated with handling the inflow are expected to impact production and operational costs at the existing mine over the long term.

The potash or sylvinite ore at PCS is a mixture of approximately 38% KCl as sylvite and 60% NaCl as halite, with an insoluble fraction, up to 2%, composed mainly of clay minerals and sulphate (Hogan 2006). Separation of the potash from the unwanted components requires a multi stage refining process. The first step, scalping, sizes and separates the oversized ore from the finer mined material. The oversized ore is crushed and mixed with salt brine to create a semi-liquid slurry. The slurry is further crushed and sized to liberate KCl particles. This mixture is then agitated and cycloned to remove clay and other deleterious particles, a process commonly referred to as de-sliming.

Following de-sliming, the potash–salt slurry is mixed with various chemicals to assist in further separation of the KCl in a process known as floatation. The treated ore slurry is placed in a series of floatation cells. When air is circulated through the slurry, particles of KCl attach to rising air bubbles forming a potash-rich froth on top which is subsequently skimmed off as a concentrate. The floatation concentrate is washed with a weak NaCl solution to dissolve any leftover salt, further improving the quality of the KCl product. Salt particles that do not attach to the air bubbles in a flotation cells sink to its bottom. This material, referred to as tails is reground to further liberate any remaining fine-grained potash to be recovered in a final flotation process. The balance of waste material, which includes salt tailings and clay slimes, are transported underground to active potash and salt stopes respectively.

During the refining process the solution of some potash and salt is inevitable and produces additional brine. Stored temporally in other underground salt stopes, this fluid is eventually pumped back to surface and circulated through an evaporator. The brine which is steam-heated until it boils, is separated into three products: purified water, a NaCl precipitate which is added to the flotation process, and a KCl and NaCl saturated brine, often referred to as the mother liquor. This mother liquor is once again heated to a boil and circulated through a series of vessels called crystallizers, resulting in a high purity KCl product which is added to the flotation concentrate. The leftover brine is returned to the refining process. The combined potash concentrate is centrifuged to remove any excess brine and subsequently dried in rotary kilns fired by indigenous sources of natural gas. Natural gas which was discovered on the PCS (NB) mining lease in 2002 and brought in to production in 2003, has resulted in very significant energy saving and a subsequent reduction in greenhouse gas emissions from the former fuel oil-fired dryers.

The dried KCl product is compacted, crushed and sized to granular and standard products. Almost all potash production is loaded on railcars for the 78 km journey to the ocean load-out terminal at the Port of Saint John. Railcar-loaded product, of a minimum of 60.0% K_2O (95.0% KCl), is quality tested before departure to the port facility. De-icing and chemical rock salt is shipped by rail and truck from the mine site or also by vessel from the Saint John port facility.

The Saint John potash terminal, operated by Furncan Marine Limited, consists of two covered storage sheds each with a maximum capacity 250 000 t for each of two potash products (granular and standard grade). Since 2000 annual shipments have generally exceeded 890 600 t annually. Granular product accounts for over half of total shipments. In 2007, 74 vessels called on the Saint John terminal for potash shipments with 51% headed for Brazil and the balance to United States (5%), Mexico (5%), the Caribbean (20%) and several other South American countries (19%) (Roulston 2007).

In 2007, PCS (NB) announced construction plans for a new, 2 000 000 t/y mine and expanded milling operation for a potash deposit discovered on its mining lease, less than a kilometre south of its present mining operation. Following its initial discovery during an exploration drilling program for natural gas in 2002, the deposit has been defined by 10 potash exploration drill holes, three natural gas wells and a 45 km^2, 3-D seismic survey. Compared to the steeply dipping nature of the potash zone presently being mined, the newly discovered resource, referred to as the Piccadilly deposit, is relatively flat, consisting of two potash zones each varying in thickness up to 18.2 m. Exploration has delineated insitu measured and indicated resources of 389 000 000 mt with an average grade of 23.5% K_2O (Roulston 2007). At a 50 % extraction rate and annual KCl production of 2 000 000 t, the new mine is reported to have a projected life of 32 years.

The new Picadilly mine, situated adjacent existing operations, will be able to utilize some of the infrastructure already in place. This will assist in expediting the construction phase and should also result in significant cost savings in the order of half a billion dollars, considering a projected \$2.2 billion investment for a 2 000 000 t/y green-fields potash operation in Saskatchewan (Potash Corporation of Saskatchewan Inc. 2007a). PCS is pursuing an ambitious construction schedule for the Piccadilly mine project, expecting completion to the predevelopment stage by 2011 at an estimated cost of \$1.7 billion (Potash Corporation of Saskatchewan Inc. 2007c). This expenditure will be complimented by \$1.2 million enhancement to the existing processing facility. A three-year, ramp-up period is expected to follow, with full production realized by 2014 (Roulston 2007). During the construction phase it is expected that 2500 person years of employment will be generated, with the addition of 140 new, full-time positions to the operations present labour requirements of 326 persons. Plans are to keep the existing mine and mill fully operational throughout the new mine's construction and development phases. Once fully developed however, underground operations will be terminated due to concerns over an inflow situation the company has been dealing with for several years.

Clover Hill–Salt Springs: discovery to production

Following its discovery in 1971 and successful negotiations surrounding an exploration and development agreement with the Potash Company of America at the Penobsquis–Plumweseep potash/salt deposit, another government-sponsored drilling program was initiated in 1973 to test the potash potential in other areas of southeastern New Brunswick. Regional gravity surveys and geologic mapping program carried out in 1971–72 assisted in the selection of three potential targets; two in the Moncton Subbasin and one near the southwestern end of the Cocagne Subbasin (Figure 2). In the Moncton Subbasin, holes were drilled on gravity lows at Salt Springs and Cornhill, 21 km southeast and 30 km northeast of Sussex respectively. A third hole was located on another gravity low, near Millstream, 4 to 5 km southwest of Sussex. A hole near Salt Springs (Figure 2) intersected 15.6 m of potash mineralization at a depth of 610 m averaging 31.6% K_2O. At Cornhill, only low grade glauberite and impure salt were intersected. The hole at Millstream was drilled to a depth of 915 m. Only a small amount of potash ore was recovered before drilling difficulties forced the hole to be abandoned.

Success at Salt Springs prompted government officials to assemble relevant geotechnical data on the discovery and invite submissions from companies interested in further exploring and developing a pre-selected 200 km^2 salt/potash reservation area in 1974. Similar to the Penobsquis–Plumweseep potash prospect awarded earlier to PCA, the New Brunswick government required a successful applicant to have the financial strength and marketing experience to bring a mine into production, should a resource of sufficient grade and size be defined. Submissions were received from eight companies with International Minerals & Chemical Corporation (Canada) Limited (IMC) emerging as the successful applicant in the fall of 1975.

IMC's exploration program, consisting of several geological, geophysical, geochemical investigations along with extensive drilling was initiated almost immediately. Geologic mapping encompassing the salt and potash reservation and surrounding area accompanied by enhanced geophysical surveys including gravity, magnetics and resistivity, assisted in the delineation of a potential resource area and facilitated the positioning of drill holes in the early phases of exploration. Twenty two holes were drilled at an approximate spacing of 800 m. Potash mineralization (sylvinite) with an average ore grade of 28 % K_2O and thicknesses ranging from 3.0 m and 42.6 m was intersected at depths greater than 600 m in all but four holes. It was reported that drilling results had defined an estimated 200 000 000 t zone of potash ore underlying 520 hectares (Anderle et al. 1979; Waugh and Urquhart 1983).

Following encouraging results from the surface exploration program, IMC prepared a preliminary development plan for the Salt Springs deposit, subsequently signing a mining lease covering 8886 hectares with the Province in 1978. A year later, it was announced that Denison Mines Ltd. had purchased the IMC lease to the Clover Hill property and would pursue an underground exploration program to evaluate the deposit further. Sinking of a 5-m diameter exploration shaft began in September 1979 and was completed in May 1982 at a bottom depth of 832 m. From the 794-m shaft level a detailed exploration program consisting of over 3 km of excavated headings and in excess of 800 m of diamond drilling (Waugh and Urquhart 1983) was undertaken. This work indicated an ore body larger than the original estimate based on the surface drilling program. Altogether, proven, probable and possible ore reserves averaging 28% K_2O were augmented to exceed 230 000 000 t (Denison Mines 1986)

In 1980, during the underground exploration phase, Denison assigned a 40% interest in the Clover Hill property to the Potash Company of Canada Limited (Potacan), an equally owned subsidiary company of Entreprise Minière et Chimique (EMC) of France and Kali und Salz A.G. (K+S) of Germany. The deal presented Denison with a doorway to global potash markets and a good fit with EMC's desire to secure supply in view of France's declining potash industry and K+S's goal of strengthening its marketing position in potash markets outside Europe. Under the new arrangement called the Denison Potacan Potash Company

(DPPC), Denison assumed the role of operations management while Potacan attended to marketing and sales.

Following the surface and underground evaluation of the deposit and exploration expenditures in excess of $26 million (DNR Files 1985), a detailed feasibility study into various technical, financial and marketing aspects for the Clover Hill project was prepared. Based on the results of this study DPPC decided to embark on the construction of a mine, surface processing facility and associated infrastructure in 1983. The new operation was designed to support an annual production capacity of 1 300 000 t of potash product (KCl at 60% K_2O) with sufficient defined ore reserves for 33 years. Two and half years after the decision to proceed with development of the property the DPPC mine was brought into production during the summer of 1985 at a cost near $350 000 000. In the fall of that year, the first potash shipment of 12 600 t of granular potash was loaded on a vessel destined for Columbia.

Mining, milling and waste management practices: the former Potacan Mining Company

The less steeply dipping nature of the potash ore zone at the Clover Hill mine compared to that at PCS (NB)'s Penobsquis potash deposit allowed DPPC to adopt a more conventional room and pillar mining method with delayed back filling. Rooms, developed in several mining panels, seldom exceeded width of 42 m. These were excavated using both continuous “road header” mining equipment (i.e., twin-rotor Marietta machines) and drill and blast techniques where favorable geological conditions existed. Ore was transported away from the working face utilizing bridge and extendible conveyors left in place to transport salt tailings from the refining process.

The milling process followed standard practices with raw potash ore sized and split into coarse and fine fractions and further concentrated by floating the potash (KCl) and separating it from salt (NaCl) in a brine solution. The floated product was dried and sized to various standard, coarse and fine product grades. Undersize particles were compacted, crushed and sized to required product specifications.

Tailings and excess brine storage and disposal at DPPC were handled differently than at PCS (NB). Temporary on surface storage of tailings and brine was permitted in the early years while sufficient space was created underground to accommodate tailings for back fill. Eventually all tailings were to be returned underground. This material was stored in a 32-hectare tailings and brine pond, lined with a thick impermeable membrane to prevent generated brine from escaping. A pipeline was constructed to allow the disposal of excess brine from the refining process and temporary tailings pond into the Bay of Fundy, 35 km south of the operation.

A 20 km railway spur line was constructed to connect DPPC with the main rail link to the potash shipping facility at the Port of Saint John. DPPC potash product arriving in 40+ car shuttle trains would be unloaded to one of two storage buildings. Rail car unloading and ship loading equipment were shared with PCS (NB). Furncan Marine manages the potash terminal. In 1984 it was reported to have a rail car offloading capacity of 1500 or more t/hr and a ship-loading capability of over 3000 t/hr (Barnett 1984). The wharf and loading basin is designed to handle ships near 40 000 t deadweight.

The DPPC mine underwent restructuring in 1991 when financial difficulties prompted the sale of Denison Mines interests in the operation to its Potacan partners. The name of the operation was subsequently changed to the Potacan Mining Company (PMC).

Throughout most of its 12 year operation PMC maintained production levels greater than 75% of its rated 1 300 000 t/yr production capacity. With a work force of 400 to 500, it had established itself as New Brunswick's largest potash mining and milling facility. In the spring of 1997, a serious inflow of water occurred in the underground workings. Following six months of several unsuccessful attempts to reduce the inflow to manageable levels, officials with PMC's parent company, The Potash Company of Canada, announced the permanent suspension of mining operations and the subsequent closure of the Clover Hill facility. A plan was implemented to dispose of all surface tailings and carry out necessary remedial work for the permanent shut down of the site. This unfortunate incident had not only reduced New Brunswick's potash production by two thirds but had resulted in the loss of an important mineral resource, the demise of hundreds of jobs and a considerable set back to the regional economy of southeastern New Brunswick.

Early in 1998, The Potash Corporation of Saskatchewan Inc. purchased the former Potacan operation. It is now called Potash Corporation of Saskatchewan Inc. (Cassidy Lake Division). Up until 2003, the facility utilized the former mills 1 000 000 t/yr compaction capacity and other related infrastructure to upgrade standard grade product imported from other PCS Saskatchewan-based production facilities to higher value granular material to supply markets in eastern Canada and the United States. At present the former operation's tailings pond and pipeline serves a key function in the disposal of the excess brine resulting from a water inflow from the PCS (NB) mine near Sussex.

Cocagne Subbasin

Millstream: discovery and exploration

Windsor Group evaporites and confirmed deposits of potash occur in a structural depocentre referred to as the Case Syncline near the western end of the Cocagne Subbasin at Millstream, about 8 km west of Sussex (Figure 2). The syncline, fault bound to the north and south, has a width of about 1 km and a strike length of approximately 6 km. Following its initial discovery in 1973 by government-sponsored drilling of a gravity low, an exploration agreement for the Millstream potash prospect was eventually signed with BP Resources Canada Limited (BPRC). In 1981, BPRC began an extensive exploration program on the eastern half of the 10 118 hectare Millstream prospect. Eleven boreholes, surface seismic and other geophysical surveys confirmed a substantial resource of potassium and magnesium bearing chloride. The deposit, 950 to 1050 m below surface, was found to consist of several sylvinite (potash) zones with apparent thicknesses up to 38 m with intervening zones of carnallitic (potassium-magnesium) halite up to 68 m thick. BP estimated a geological insitu potash resource of 256 000 000 t with an average ore grade of 20.6 % K_2O over an area of 2.75 to 3 km^2.

After signing a mining lease with the New Brunswick Government in 1985, BPRC continued into the early 1990s to refine a preliminary development plan for the Millstream potash deposit. Much of this work centred on the drilling of a shaft pilot hole and plans surrounding the implementation of an underground exploration program. The feasibility of establishing a mine and surface infrastructure based on 1 200 000 t/yr capacity was undertaken and attempts were made to secure suitable partnership to move the Millstream project forward. A recessionary investment climate of the time and other issues provided serious challenges to the viability of the Millstream project. Following a major corporate restructuring in 1992, BPRC opted to relinquish all its mining assets including its New Brunswick potash prospect at Millstream, deciding instead to consolidate its business interests in exploration and development of its petroleum resources.

In 1995 a request for proposals from exploration and development interests for the continued assessment of the Millstream potash deposit was once again issued by the New Brunswick Government. International Minerals and Chemical (Canada) Global Limited (IMC Canada), one of several parties interested in the prospect, was subsequently chosen to further evaluate the deposit and move it forward toward development. The company proposed a three-year exploration program that began re-examining the extensive anthology of geotechnical data collected on the deposit in order to evaluate the viability of various mining strategies (Webb, Allard and Stewart, in press). Depending on the outcome of this geological review, a 3-D seismic survey followed by a study investigating the feasibility of moving the Millstream prospect to the development phase was proposed.

Within a year of initiating the Millstream reassessment and in the wake of a major corporate reorganization resulting in the creation of a new company IMC KALIUM, it was decided for various reasons not to proceed further with the re-evaluation of Millstream. Mineral rights to the property were once again returned to the Province by the end of 1997 and the prospect presently remains undeveloped.

Interest in the Millstream Prospect, since its discovery over 25 years ago, has been focused on its potash resource. However, a potentially large magnesium resource in the form of carnallitite, a physical admixture of the minerals, carnallite ($KClMgCl_2 \cdot 6H_2O$) and halite ($NaCl$), found associated with the prospect has received little attention. Very preliminary estimates indicate a potential carnallitite resource in excess of 100 000 000 t. It is important to note that less than half of the Millstream Prospect has been adequately explored. There remains a very good possibility that additional potash and magnesium resources may be present to the northeast and southwest of the former area explored by BP. Pending more detailed examination, it would seem that development of the Millstream property could well depend on establishing a suitable method for multi-element recovery and co-product (potassium, magnesium, and sodium chlorides) generation. Considering alternative methods of extraction, like solution mining, the regional availability of natural gas and its strategic location near an established rail line with direct links to a proven port facility less than 60 km away, the evaporite deposits at Millstream may well deserve further re-examination.

Possible Additional Potash Resource Potential in New Brunswick

Unprecedented and dramatic changes in both consumption and production of potash over the last few years are reflected in major adjustments to demand and supply to global fertilizer markets. The widening potash supply-demand gap is not only driving massive production capacity expansions at existing mines throughout North America but is also providing considerable incentive among all manner of companies to explore, evaluate and develop new potential resource opportunities. Consequently, a new, 2 000 000 t/y potash mining and processing facility is presently under construction in New Brunswick near Sussex. As well, preliminary geological data suggest unqualified potential for additional potash exploration in other parts of the Province.

Successful exploration and resulting development of potash-bearing Windsor Group evaporite deposits in the Sussex area of southeastern New Brunswick amply demonstrate the geological attributes associated with major potash deposits. Given the characteristics of confirmed deposits and subsurface indications of Windsor Group evaporites elsewhere in the Province, the presence of undiscovered potash resources can not be ruled out. To date only a small portion of the Province with possibilities for potash mineralization has actually been explored.

Throughout southern New Brunswick several favourable areas of interest in this regard have been tentatively identified (Figure 2). These are found in parts of the Moncton, Cocagne, Sackville and Cumberland subbasins, and in the extreme southern parts of the New Brunswick Platform. The level of detail related to the geology of the Windsor Group evaporites in these areas varies considerably. More basic data must be collected before a reasonable assessment of an area's potash potential is attempted.

Moncton Subbasin

In addition to the successful potash developments in the Moncton Subbasin potential for additional exploration may also exist outside of areas of known resources or areas presently held for future exploration and development. There are four areas of interest in this regard (Figure 2), two of which are situated in the Marchbank Syncline 15 to 25 km southwest of Sussex. One of these is situated primarily southwest and on strike of the former Potacan mining operation in the Salt Springs–Salina–Smithtown area. Since its closure in 1996, the western limits of the Potacan Clover Hill potash mine have not been clearly defined. Available gravity data (Hassan 2000) suggest a continuation of subsurface evaporites in this area and surface salt brines with anomalous potassium and magnesium values make it a reasonable exploration target for potash and related carnallitite mineralization. Another exploration target in this area is the possible extension of the evaporite body northeast of the former mine in the Poodiac–Jefferies Corner–Hammondvale–Markamville area where platform carbonates of the Windsor Group (Gays River Formation) are exposed along the southern margin of the Marchbank Syncline with thick sulphate deposits found in the subsurface to the north, near Hammondvale (Figure 2).

Remote possibilities for potash mineralization also exist in two other parts of the Moncton Subbasin. One is situated northeast of the PCS Potash (NB Division) Mining Lease in a triangular shaped area bounded by Petitcodiac to the north, Pollett River to the south and The Glades to the east (Figure 2). Gravity data and drill-hole information from a hole near Pollett River indicate that Windsor Group evaporates occur in the subsurface, however the presence of potash mineralization has not been confirmed (Figure 2). The other extends over a narrow 60 km^2 area southwest of Norton to Hampton. Regional geologic mapping in this area indicates it is underlain by sedimentary clastics rocks of the Mabou Group which typically overlie Windsor Group strata throughout southern New Brunswick. At present additional supportive geological and geophysical data (i.e., gravity coverage) in this prospective area is very limited and the presence and nature of Windsor Group evaporites remains speculative.

Cocagne Subbasin

In addition to potash resources already defined at Millstream, prospects are excellent for an expanded potash resource and a possible magnesium resource in the Cocagne Subbasin. At Millstream, potash resources identified to date occupy less than 50% of the area considered geologically favourable for this type of deposit. Beyond the area formerly explored by BP Resources in the early 1980s, the Millstream evaporite deposit is considered open for several kilometres to the southwest and similarly open for a few kilometres to the northeast (Figure 2).

Sackville and Cumberland Subbasins

The Sackville and Cumberland subbasins situated in the southeastern part of the Province offer several interesting potential exploration targets for subsurface Windsor Group evaporites with untested possibilities for potash mineralization (Figure 2). Geological evaluation of the potash potential in these Carboniferous basins, however, is somewhat compromised by limited borehole control and sparse outcrop. What is known has been extracted largely from seismic, gravimetric and related geophysical surveys. The structural evolution of these basins is complicated by complexly folded and faulted Early Carboniferous strata including Windsor Group evaporites (St. Peter 1993).

The presence of Windsor Group evaporites in the region is verified by three bore holes in the Dorchester–Coppermine Hill area near the northwestern fault-bound limit of the Sackville Subbasin. At Dorchester, holes drilled by Shell Oil in 1949 and Imperial Oil in 1960 encountered thick deposits of salt and sulphate. The Shell borehole reported a drilled intersection of salt 977 m thick below a depth of 542 m while the Imperial borehole intersected 795 m of salt at a depth of 1 542 m. In 2000, a third bore hole located several kilometres east of Dorchester, at Coppermine Hill, also intersected 177 m of impure salt at a depth 1964 m (see NB Department of Natural Resources: Borehole Data Base, URN 711). No potash mineralization has been reported in any of these holes, however its apparent absence is not considered conclusive evidence that such mineralization does not occur elsewhere. Importantly, potash mineralization is reported from similar deposits from the Cumberland Subbasin of Nova Scotia near Malagash, Pugwash and Oxford. It is therefore reasonable to assume that potash may also occur in the Sackville and Cumberland subbasins of New Brunswick.

Regional gravity and seismic surveys have identified several potential Windsor Group evaporite structures throughout this part of southeastern New Brunswick (Figure 2). A configuration of gravity lows suggests several structural trends occupied by masses of salt adjacent to or bounded by major regional and related fault structures. Areas of interest in this regard include Johnson Creek, Morice Pond, Sackville, Aulac, Point de Bute, Jolicure Lakes, and Baie Verte–Uniacke Hill in the Sackville Subbasin, and Cape Maringouin and Shepody in New Brunswick's part of the Cumberland Subbasin. No borehole data exist for these areas so the true nature of the salt is unknown.

New Brunswick Platform

The New Brunswick Platform comprises nearly 20 000 km^2 of central and eastern New Brunswick (Figure 2). In general the platform is underlain by Early to Late Carboniferous sedimentary clastics and felsic to mafic volcanic rocks. Bedrock exposure throughout the platform region is generally poor except along its margins, in coastal areas and adjacent some of its larger rivers and related tributaries. Outcrop of Windsor Group strata on the platform are restricted to carbonates and associated sedimentary clastics along its southern margin between Shin Creek and Shannon, respectively 60 and 50 km northwest and north of Saint John (Figure 2). The Windsor Group, Mabou Group and other Early Carboniferous sedimentary rocks are overlain by flat-lying to gently dipping Late Carboniferous sedimentary clastics of the Cumberland and Pictou groups in this area of the platform.

It is difficult to evaluate the potash potential of the New Brunswick Platform. Most geologic investigations of the region are of a reconnaissance nature. Among some of the most notable regional geological investigations are a shallow drilling program consisting of holes positioned at roughly 10 km centres throughout the Platform area (Ball et al. 1981). Intended to assist in the location of shallow coal deposits these holes seldom exceeded depths of 122 m but provided interesting geological and geochemical data with respect to the possible occurrence of subsurface evaporite deposits. Regional gravimetric maps and an interpretation of aeromagnetic data and limited seismic coverage have also contributed to a better understanding of the region's geology, its subsurface topography and its mineral potential. Deep borehole data on the Platform is limited to only a few holes, and most of these have been drilled in its northern half in areas not considered to be underlain by Windsor Group evaporite strata (Howie 1988; Atlantic Geoscience Society 2001). Recently, a deep borehole drilled south of Fredericton in a basinal depocentre (the Marysville Subbasin) near the southwestern limit of the Platform indicated no Windsor Group strata at this location (see NB Department of Natural Resources: Borehole Data Base, URN 734). It is of interest to note proposed geologic assessments of parts of the platform in conjunction with oil and gas exploration in 2008-09 may assist in evaluating the regions evaporite potential.

To date, a preliminary geologic interpretation of Platform geology suggests several areas of uplifted and down-faulted basement terrain (horst and graben structures). A significant graben-like structure is associated with several gravity lows and locally anomalous formational waters with respect to potassium and chloride extends southwest of Richibucto on the coast of the Northumberland Straight to an area east of Chipman (Figure 2).

Stratigraphic and facies analysis of Windsor Group carbonates and related rock exposures along the southern margin of the platform suggest similarities with Windsor strata in parts of the Cocagne Subbasin to the south where potash-bearing evaporites at Millstream are known to occur. If this can be demonstrated further, Windsor evaporites may occur beneath the Late Carboniferous cover rocks of the New Brunswick Platform particularly near its boundary with the Cocagne Subbasin and basement rocks to the south. A region extending from the Grand Lake area northeast to Bouctouche is characterized by formational waters with comparatively high potassium values and several broad gravity anomalies (Figure 2). Although saline water wells in parts of the Platform are not uncommon and some may be explained by perched relict glacial seawater (Webb 1981), others may require further analysis to determine their source.

The extension of Windsor Group evaporites onto the New Brunswick Platform is considered only a possibility. If present, such rocks are likely to be preserved in the intervening down-faulted graben-like configurations between basement highs or in equivalent basin depressions behind restrictive basement arches or similar structures. It remains a possibility that because of its remoteness from areas of intense deformation in other Carboniferous basins to the southeast, evaporite horizons on the Platform may be flat lying or gently dipping and difficult to identify by traditional gravity methods. Given the limitations and the regional nature of most gravity data collected on the Platform to date, more detailed gravity and applied modelling studies, supplemented by other appropriate geophysical surveys including seismic, would help identify potential evaporite structures. A follow up deep drilling initiative in favourable areas will be required at some stage to verify geophysical interpretations and the nature of proposed evaporite deposits.

Although speculative, there are several areas in the southern part of the platform that would serve as reasonable starting points for additional investigation (Figure 2). These include the Grand–Washademoak–Maquapit lakes area, an area extending from Cambridge Narrows northeast to Coles Island and an areas near Mill Brook; the Chipman, Harcourt–Adamsville, and Richibucto areas; and areas east of Canaan Rapids, northwest of Upper Gaspereau and possibly east of Noonan. Anomalous areas adjacent the southern boundary of the Platform between the Saint John River and Havelock are particularly appealing given their proximity to potash-bearing Windsor Group evaporites in the western end of the Cocagne Subbasin at Millstream, a few kilometres west of Sussex.

Conclusions

Improved economics for green-fields potash exploration and development is being driven by a burgeoning demand and exceptionally strong prices in world fertilizer markets. As the market for potash continues at an unprecedented high, a number of interested companies are pressing to secure and evaluate prospective potash resource areas throughout North America while existing producers embark on massive expansions to production capacity. In consideration of these recent developments, the potential for renewed interest in potash exploration in New Brunswick remains a possibility. Only a small portion of the Province has been effectively explored for Windsor Group evaporites and associated potash mineralization. More detailed work is clearly required using modern exploration technology to properly assess these areas of interest.

Potash deposits have been found at three locations in the Moncton Subbasin and at one in the Cocagne Subbasin in southeastern New Brunswick. In the Moncton Subbasin near Sussex, potash discoveries have been and continue to be developed into world class potash operations. A sizeable potash resource confirmed in the Cocagne Subbasin, the Millstream deposit, may also require re-evaluation in consideration of recent developments in extractive and process technologies, a potential for co-product generation and changes in world potash markets.

The expectation of additional potash or related salt resources like potassium and magnesium bearing carnallitite occurring as extensions to known deposits in the Moncton and Cocagne subbasins seems reasonable in light of existing geotechnical information. Areas adjacent the former Potacan potash mining operation at Clover Hill, northeast of the present PCS (NB) Mining Lease, and prospects peripheral to an explored area at Millstream all have untested potash exploration potential. A significant, yet to be verified, potash resource associated with Windsor Group evaporite structures in the Sackville and Cumberland subbasins of southeastern New Brunswick remains a possibility. Although clear evidence of Windsor Group evaporites on the New Brunswick Platform is not yet confirmed, its southern and eastern parts appear worthy of more detailed investigation to properly assess the region's potash potential.

Salt, potash and related evaporite minerals are withdrawn from prospecting and staking in New Brunswick. Up until very recently, it has generally been the practice to grant prospective exploration areas on a submission - agreement basis. In light of the latest unprecedented developments in the world's potash industry and other interests in New Brunswick's salt deposits, the Province's potash and related evaporite exploration and development policies are presently being reviewed to ensure these resources are developed to their maximum potential in an efficient and responsible manner. Potash and related evaporite exploration interests are therefore, temporarily on-hold until appropriate policy amendments are implemented that reflect the best exploration and potential development options for these important resources. Consequently, the time is right for interested parties to acquaint themselves with existing data on the Province's evaporite deposits, establishing a sound geologic foundation for informed exploration decisions when potential target areas are made available.

For more information on opportunities for potash exploration and development in New Brunswick contact:

Geological and geotechnical matters

Tim C. Webb, P.Geo.
Industrial Minerals Geologist
Geological Surveys Branch
N.B. Department of Natural Resources
Telephone: 506-453-2206
E-mail: Tim.Webb@gnb.ca

Mineral rights and land tenure issues

Sam McEwan, P.Eng.
Director
Minerals & Petroleum Development Branch
N.B. Department of Natural Resources
Telephone: 506-453-2206
E-mail: Sam.McEwan@gnb.ca

SELECTED REFERENCES

Anderle, J.P., Crosby, K.S., and Waugh, D.C.E. 1979. Potash at Salt Springs, New Brunswick. Economic Geology, **74**, pp. 389–396.

Ball, F.D., Sullivan, R.M., and Peach, A.R. 1981. Carboniferous Drilling Project. New Brunswick Department of Natural Resources, Mineral Development Branch, Report of Investigations 18, 109 p.

Barnett, D.E. 1984. Potash production in New Brunswick. Fertilizer International, No. **186**, pp. 38-43.

Denison Mines, 1986. Annual Report for 1985. pp. 18-21.

Atlantic Geoscience Society. 2001. The Last Billion Years. Nimbus Publishing Ltd., Halifax, Nova Scotia, pp. 102–108.

Chandra, J., Chandra, S., Wallace, J., Williams, D., and Webb, T. 1982. Gravity survey of New Brunswick. New Brunswick Department of Natural Resources, Mineral Resources Division, Open File Report 82-11, 70 p.

Gussow, W.C. 1953. Carboniferous stratigraphy and structural geology of New Brunswick, Canada. Bulletin of the American Association of Petroleum Geologists, **37**, No. 7, pp. 1713–1816.

Earth Physics Branch. 1977. Bouguer anomaly map of New Brunswick. (1:500 000 scale), Open File No. 77-4, Department of Energy, Mines and Resources, Canada.

Hassan, H.H. 2000. Digital compilation of gravity data for New Brunswick. New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, Open File Report 2000-1, 212 p.

Hogan, M.H. 2006. PCS Potash (New Brunswick Division), Fact Sheet 2006, 12 p.

Howie, R.D. 1988. Upper Paleozoic evaporites in Atlantic Canada. Geological Survey of Canada Bulletin, **380**, 20 p.

Industrial Minerals. 2008. Mosaic 5.1m. Tpa potash expansion as contract prices soar. Industrial Minerals, May Issue, No. 488, p. 19.

Kingston, P.W., and Dickie, D.E. 1979. Geology of New Brunswick potash deposits. Canadian Institute of Mining and Metallurgy Bulletin, **72**, No. 802, pp. 134–141.

McCutcheon, S. R.1983. Potash in the central New Brunswick Platform. Canadian Institute of Mining and Metallurgy Bulletin, **76**, No. 857, pp. 70–76.

McCutcheon, S.R., McLeod, M.J., Webb, T.C., Roulston, B.V., and Waugh, D.C.E. 1980. Stratigraphy and paleoenvironment of the Windsor Group in New Brunswick. Geological Association of Canada/Mineralogical Association of Canada, Halifax, Nova Scotia, Field Trip Guidebook, No. 5, 39 p.

McCutcheon, S.R.; Roulston, B.V., and Webb, T.C. 1985. Stratigraphy and paleoenvironmental setting of the Windsor group potash deposits, southeastern New Brunswick. Geological Association of Canada Mineralogical Association of Canada, Fredericton, New Brunswick, 1985, Excursion 5, p. 32.

Martel, A.T., 1987. Seismic stratigraphy and hydrocarbon potential of the strike-slip Sackville sub-basin, New Brunswick. Canadian Society of Petroleum Geologists, Memoir **12** (1987), pp. 319–334.

New Brunswick Department of Natural Resources. 2009. Bedrock Lexicon Database. URL < http://www1.gnb.ca/0078/GeoscienceDatabase/Lexicon/GeoSearch-e.asp >. Accessed January 2009.

New Brunswick Department of Natural Resources. 2009. Borehole Database. URL < http://www1.gnb.ca/0078/GeoscienceDatabase/Borehole/Search.asp >. Accessed January 2009.

New Brunswick Department of Natural Resources and Energy. 2000. Bedrock Geology of New Brunswick, Minerals and Energy Division, Map NR-1 (2000 Edition), Scale 1:500 000.

O'Driscoll, M. 2008. Where there's muck there's brass. Industrial Minerals, May Issue, No. 488, p. 27.

Partridge, J., and Hoffman, A. 2008. China deal sends potash soaring. Globe and Mail, 16 April, 2008, < http:www.reportonbusiness.com/servlet/story/RTGAM.20080416.wrpotash17/BNStory/Business/home >. Accessed December 2008.

Petrie, L.M., and St. Peter, C.J. 2003. Gravity survey of the Fredericton-Oromocto area, New Brunswick - parts of (21 G/09, 21 G/10, 21 G/15, 21 G/16, 21 J/01, and 21 J/02). New Brunswick Department of Natural Resources; Minerals, Policy and Planning Division, Open File Report 2003-14, 18 p.

Potash Corporation of Saskatchewan Inc. 2007a. Potash Corp announces new potash mine and mill expansion in New Brunswick. News Release, July 20, 2007, 2 p.

Potash Corporation of Saskatchewan Inc. 2007b. Yesterday, today and tomorrow. Annual Report of Form 10-K for the year ended December 31, 2007. Part I, p. 4.

Potash Corporation of Saskatchewan Inc. 2007c. Operations highlights. PotashCorp 2007 Online Annual Report, < http://www.potashcorp.com/investor_relations/financial_performance/annual_results/annual_reports_archive/2007/html/our_story/operations/ >. Accessed August 2008.

Potter, R.R.1967. Dorchester salt deposit, New Brunswick. Reference 9**,** New Brunswick Department of Natural Resources, Minerals Division, 8 p.

Potter, R.R. 1981. New Brunswick’s potash potential. New Brunswick Department of Natural Resources, Minerals Division, Reference 101, 27 p.

Roulston, B.V. 1995. Canada’s zero effluent potash mine. *In* 29^{th} Forum on the Geology of Industrial Minerals: Proceedings. *Edited by* M. Tabillo and D.L. Dupras. California Department of Conservation, Division of Mines and Geology Special Publication 110, pp. 261–267.

Roulston, B.V. 2007. Picadilly potash project. A presentation at Exploration and Mining New Brunswick, 2007. New Brunswick Department of Natural Resources; Minerals, Policy and Planning Division, Fredericton, NB, November 4–7, 2007, 38 p.

Roulston, B.V., and Waugh, D.C.E. 1985. Stratigraphic comparison of the Mississippian potash deposits in New Brunswick, Canada. *In* Sixth International Symposium on Salt – 1983, *Edited by* B.C. Schrieber and H.L. Harner. The Salt Institute, Alexandria, Virginia, 1, pp.115–129.

Roulston, B.V., Webb, T.C., and Monahan, M.E. 1995. Stratigraphy and depositional synthesis of middle to late Viséan evaporates in part of the Moncton Subbasin, New Brunswick, Canada. *In* Proceedings: 30^{th} Forum on the Geology of Minerals (1994), *Edited by* S.A.A.

Merlini, New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, Miscellaneous Report 16, pp. 171–179.

Smith, E.A. (compiler) 2006a. Bedrock Geology of Southwestern New Brunswick (NTS 21 G and part of 21 B). New Brunswick Department of Natural Resources; Minerals, Policy and Planning Division, Map NR-5 (Second Edition).

Smith, E.A. (compiler) 2006b. Bedrock Geology of Southeastern New Brunswick (NTS 21 H). New Brunswick Department of Natural Resources; Minerals, Policy and Planning Division, Map NR-6 (Second Edition).

St. Peter, C. 1993. Maritimes Basin evolution: key geologic and seismic evidence from the Moncton Subbasin of New Brunswick. Atlantic Geology, **29**, pp. 233–270.

St. Peter, C. 2006. Geological relationship between the Cocagne Subbasin and Indian Mountain Deformed Zone, Maritimes Basin, New Brunswick, Canada. *In* Geological Investigations in New Brunswick for 2005. *Edited by* G.L. Martin. New Brunswick Department of Natural Resources; Minerals, Policy and Planning Division, Mineral Resource Report 2006-3, pp. 103–183.

Waugh D.C.E., and Urqhart, B.R. 1983. The geology of the Denison-Potacan's New Brunswick potash deposit. *In* Sixth International Symposium on Salt – 1983, *Edited by* B.C. Schrieber and H.L. Harner, The Salt Institute, Alexandria, Virginia, 1, pp. 85–98.

Webb, T.C. 1977. The geology of New Brunswick glauberite deposits. New Brunswick Department of Natural Resources, Mineral Resources Branch, Open File Report 77-15 (revised 1980), 29 p.

Webb, T.C. 1981. Origin of brackish formational ground waters in the Pennsylvanian of New Brunswick. New Brunswick Department of Natural Resources, Mineral Development Branch, Open File 82-5, 24 p.

Webb, T. 1984. New Brunswick potash deposits. In Geology of Industrial Minerals in Canada. The Canadian Institute Mining and Metallurgy, Special Volume **29**, pp. 41–47.

Webb, T.C. 1994. The Millstream potash prospect, Kings County, New Brunswick. New Brunswick Department of Natural Resources and Energy; Minerals Division, Reference 208, 24 p.

Webb, T., and Barnett, D.E. 1986. New Brunswick potash: Discovery to production. New Brunswick Department of Natural Resources, Minerals Division, Reference 128, 47 p.

Webb, T.C., Allard, S., and Stewart, H.J. (in press). Geotechnical data for the Millstream Potash Prospect, Lower Millstream (NTS 21 H/12), Kings County, south–central New Brunswick. New Brunswick Department of Natural Resources; Minerals, Policy and Planning Division.

Wilson, P. 2003. Stratigraphy, evaporate structure and tectonic history in the McCully area, southern New Brunswick: Preliminary results. In Current Research 2002, Edited by B.M.W. Carroll, New Brunswick Department of Natural Resources; Minerals, Policy and Planning Division, Mineral Resource Report 2003-4, pp.101–121.

Wilson, P. 2005. Stratigraphy, structural geology and tectonic history of the McCully area, Moncton Subbasin, southeastern New Brunswick. New Brunswick Department of Natural Resources; Minerals, Policy and Planning Division, Mineral Resource Report 2005-5, 104 p.

Wilson, P., White, J.C., and Roulston, B.V. 2006. Structural Geology of the Penobsquis salt structure: late Bashkirian inversion in the Moncton Basin, eastern Canada, Canadian Journal of Earth Sciences, **43**, pp. 405–419.

Wilson, P., and White, J.C. 2006.Tectonic evolution of the Moncton Basin, New Brunswick, eastern Canada: new evidence from field and sub-surface data. Bulletin of Canadian Petroleum Geology, **54**, No. 4, pp. 319–336.