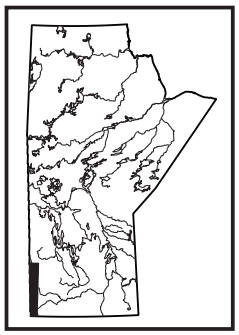
GS-8 Potash deposits in the Devonian Prairie Evaporite, southwestern Manitoba (parts of NTS 62F, K)

by M.P.B. Nicolas



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Summary

Potash deposits occur within the Devonian Prairie Evaporite in southwestern Manitoba. The Esterhazy and White Bear members are the potash beds that extend eastward into Manitoba from Saskatchewan. The known area of potash occurrence in Manitoba can be subdivided into three subareas: 1) the Russell-McAuley area, covering townships 14 to 21, ranges 27 to 29W1; 2) the Daly-Sinclair area, covering townships 5 to 11, ranges 27 to 29W1; and 3) the Pierson area, occurring in township 1, range 28W1. These are separated from the others by broad areas with no potash occurrence in the Prairie Evaporite. The only area that has been actively explored for potash is the Russell-McAuley area, where the Esterhazy Member is of sufficient thickness and grade to sustain potentially economic underground potash mining. The Daly-Sinclair and Pierson areas have not been explored due to the development of petroleum resources, which precludes the co-development of potash resources. Accordingly, there are no resource estimates for these areas.

Resource estimates for the Russell-McAuley area can be subdivided into northern (Russell deposit) and southern (St. Lazare deposit) blocks, reflecting the pattern of historical potash dispositions. The Russell deposit has a resource estimate of 392 million tonnes with an average grade of 22.5% K_2O and a mining thickness of 2.74 m. The historical resource estimate for the St. Lazare deposit is 650 million tonnes with an average grade of 20.9% K_2O, a 16% cut-off grade and a mining thickness of 2.44 m.

During the last three decades, changes to provincial mining and mineral statutes have resulted in the release of new information in assessment files that enables a detailed look at the structure of, and anomalies within, the Prairie Evaporite in the Russell-McAuley area. These anomalies include several Winnipegosis mound complexes throughout the area, occasional collapse structures and basement faults. The structure on the stratigraphic top of the Prairie Evaporite was found to follow the expected regional northwest-southeast trend, with a gentle dip to the southwest. Depth to the top of the formation is between 875 and 1050 m, and isopachs decrease eastward up to the dissolution edge, with a maximum measured at 139 m.

Introduction

Potash resources, which generally contain the mineral sylvite (KCl), are mined for their potassium content and are used dominantly in the fertilizer industry to help increase crop yields. Other markets for potash include glass, ceramics, soaps and detergents, synthetic rubber and chemicals. The demand and price for potash are affected by fluctuating market prices just as any other commodity; however, with a growing world population, the demand for potash is expected to continue to grow in the years to come.

Canada boasts some of the richest and largest potash deposits in the world. Deposits are exploited in New Brunswick and Saskatchewan, the latter province being responsible for the bulk of Canadian potash production. The Saskatchewan potash deposits occur in the upper beds of the Devonian Prairie Evaporite, a thick formation consisting predominantly of thick beds of halite, interbedded with anhydrite and potash, that are hosted within the Western Canada Sedimentary Basin. This formation and two of its four potash members extend into southwestern Manitoba, where ore grades and tonnages are comparable to nearby, active, long-lived potash mines in Saskatchewan. Nearby mines include Potash Corporation of Saskatchewan's (PCS) Rocanville mine and The Mosaic Company's Esterhazy K1 and K2 mines.

Exploration for potash in Manitoba has been intermittent for many decades since potash exploration targeting the eastern extension of the prolific Saskatchewan deposits started in 1959. Drillhole and coring programs, supported by 2-D and 3-D seismic surveys, indicate that Manitoba has potentially economically mineable, sizable potash deposits with geological conditions similar to those in Saskatchewan.

During the last few years, the Manitoba Geological Survey has partnered with the Manitoba Potash Corporation to provide it with technical geological data for its potash assets.

Bannatyne (1983) provided the first detailed assessment of the potash deposits in Manitoba. Since that time, there have been new data acquisitions from various exploration companies, including new resource assessments for an expanded area due to the release of assessment data (Bamburak, 2007). This report provides a brief summary of some of the new information acquired on Manitoba's potash deposits.

Regional and local geology

The known area of potash occurrence in Manitoba covers 2 247 km^2 and can be subdivided into three areas

(Figure GS-8-1): 1) the Russell-McAuley area, covering townships 14 to 21, ranges 27 to 29W1, with an area of 1034 km^2; 2) the Daly-Sinclair area, covering townships 5 to 11, ranges 27 to 29W1, with an area of 1157 km^2; and 3) the Pierson area, covering township 1, range 28W1, with an area of 56 km^2.

The strata in the vicinity of these deposits comprise Paleozoic-, Mesozoic- and Cenozoic-age rocks that form a basinward-thickening, southwesterly sloping wedge, reaching a total thickness of 2.3 km in the extreme southwestern corner of Manitoba. The sequences within this sedimentary package were deposited in two sedimentary basins, the Williston Basin and the Elk Point Basin, both of which are sub-basins of the Western Canada Sedimentary Basin. The potash-bearing Devonian-age Prairie Evaporite was deposited within the Elk Point Basin (Figure GS-8-2). This formation overlies the limestones and dolostones of the Winnipegosis Formation, and is over-

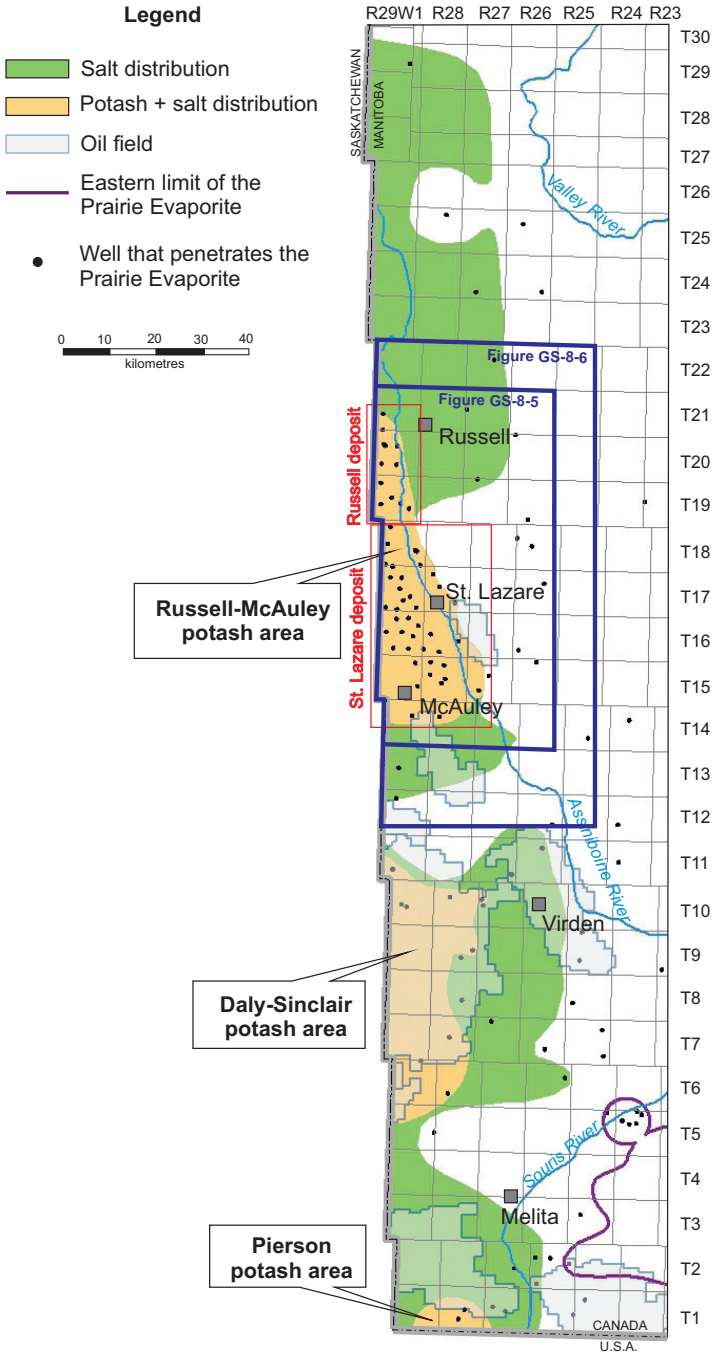

Figure GS-8-1: *Southwestern Manitoba, showing the distribution of salt and potash + salt, oil fields, and wells that penetrate the Prairie Evaporite. The three main areas of potash occurrence are shown, as are the northern and southern blocks of the Russell-McAuley area. The salt-dissolution edge is equivalent to the eastern limit of the salt and potash + salt distribution areas.*

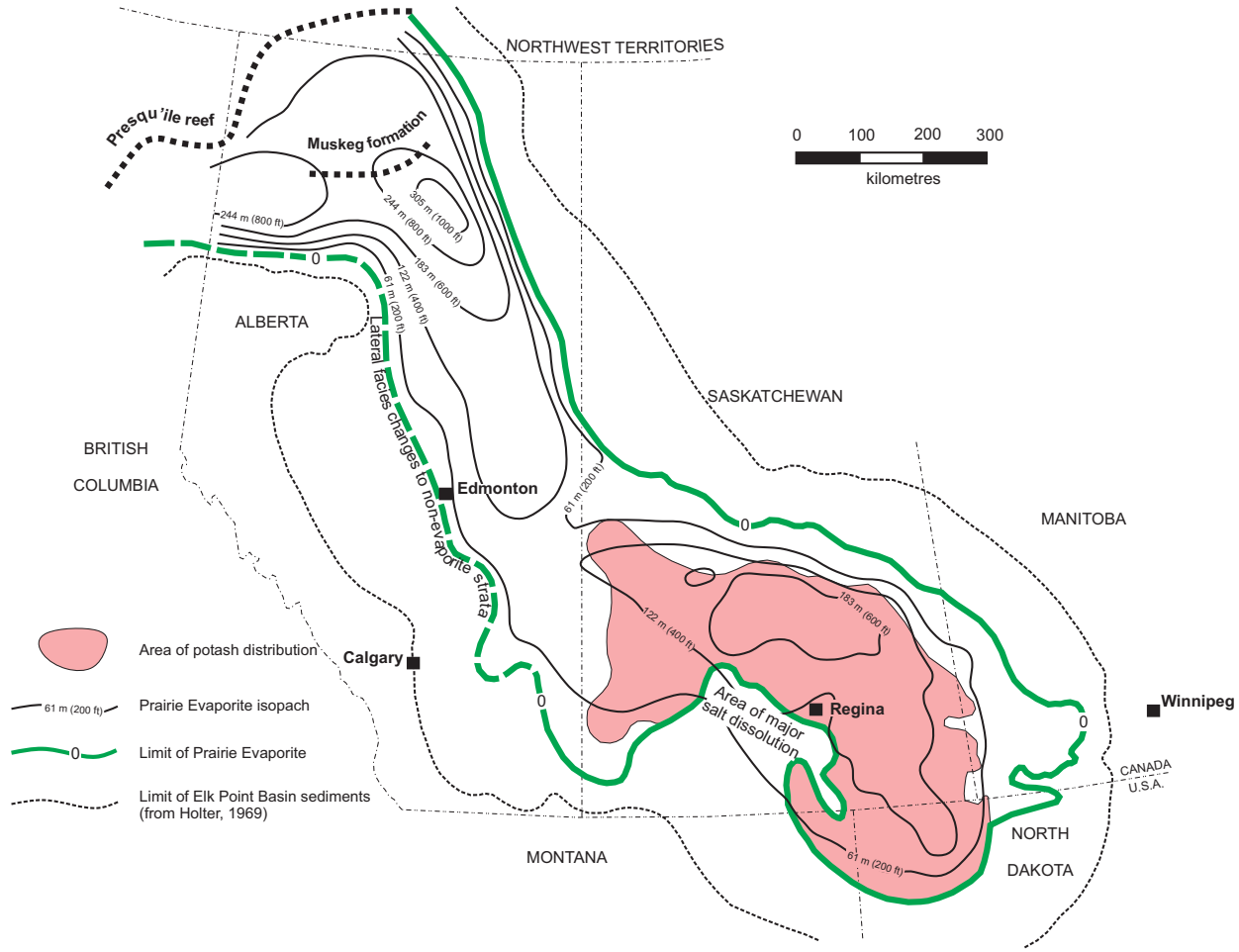

Figure GS-8-2: *Distribution and isopachs of the Prairie Evaporite in the Elk Point Basin, and area of potash occurrence (modified from Holter, 1969; Worsley and Fuzesy, 1979; Bannatyne, 1983).*

lain by the Second Red Bed Member of the Dawson Bay Formation.

The Prairie Evaporite consists mainly of halite, with minor interbedded anhydrite (Shell Lake Member and basal Winnipegosis transitional beds) and interstitial dolomitic mudstone, and up to four localized potash beds, only two of which (Esterhazy and White Bear) extend into Manitoba (Figure GS-8-3). East of the salt-dissolution edge (where the salt-dissolution edge is represented by the eastern limit of the area of salt distribution in Figure GS-8-1), the formation thins considerably and consists of brecciated anhydrite and dolomite mudstone. Within the basin, the formation can exceed 210 m in thickness and lies at a depth of 200–2750 m below surface. In Manitoba, the thickest isopach measured in a drillhole for the Prairie Evaporite is 133 m, and the formation rapidly thins east toward the salt-dissolution edge. The Prairie Evaporite salt-dissolution edge runs roughly north-south from township 1 to 29, ranges 27 and 28W1, and represents the maximum eastern extent of salt (and potash) occurrence (Figure GS-8-1). West of the salt edge, the depths for the formation range from 600 m in the north to 2660 m in the south.

The overlying Second Red Bed Member of the Dawson Bay Formation consists of grey, brown and red shale and argillaceous mudstone that, when competent (i.e., not fractured), can act as a thin aquitard, forming a protective layer between the salt beds of the Prairie Evaporite and the overlying water-bearing carbonate beds of the Burr and Neely members of the Dawson Bay. The Burr and Neely members consist of limestone and dolomite, with some interbedded anhydrite in places, that form the lower beds of the regional Manitoba aquifer (Palombi, 2008). The Hubbard salt, which occurs near the top of the Dawson Bay, is not present in Manitoba (TGI Williston Working Group, 2008a, b).

The underlying Winnipegosis Formation consists of interbedded dolomite, dolomitic limestone and anhydrite, and forms the regional Winnipegosis aquifer (Palombi, 2008). Reef structures, both pinnacle and broad platform, within the Winnipegosis Formation have been identified on seismic surveys. These project up into the overlying

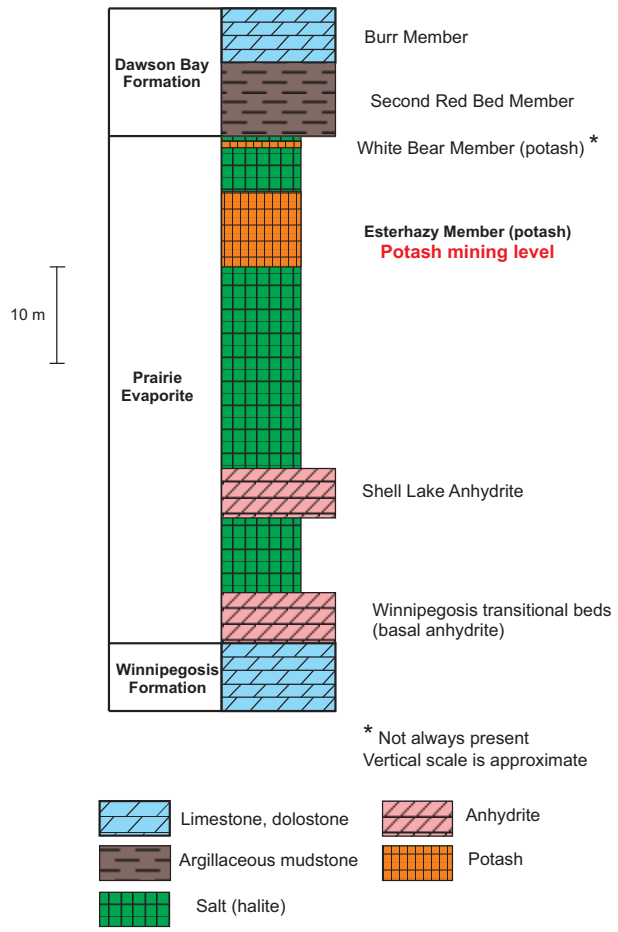

Figure GS-8-3: *Schematic stratigraphic column of the Prairie Evaporite in Manitoba.*

Prairie Evaporite in a number of locations, resulting in a localized thinning of the salt and, in some places (e.g., L.S. 8, Sec. 13, Twp. 5, Rge. 29 W 1st Mer. (abbreviated 8-13-5-29W1)), the complete dissolution of the salt beds and collapse of the overlying strata.

The upper part of the Prairie Evaporite contains four potash-bearing beds, which occur at depths between 600 and 2500 m. In ascending order, these potash beds are the Esterhazy, White Bear, Belle Plaine and Patience Lake members. These members can be up to 7 m thick and are separated from one another by halite beds. The potash members consist of sylvite, halite, carnallite and minor interstitial dolomitic mudstone. The members thin from northwest to southeast and occur at shallower depths toward the eastern edge of the basin (Figure GS-8-4). The two oldest of the four members, the Esterhazy and White Bear members, are the potash beds present in Manitoba. The Esterhazy Member, however, is the only potash-bearing bed with sufficient thickness to support potentially economic mining, since the White Bear Member is too thin to be economically exploited.

The location of the provincial border with Saskatchewan and the margin of the basin result in the Esterhazy Member being intermittently present in a narrow, elongate strip in southwestern Manitoba, beneath townships 1 to 21, ranges 27 to 29W1 (Figure GS-8-1). The potash beds dip gently to the southwest at depths ranging from 785 m near the community of Russell in the north to approximately 2670 m near the Canada–United States border in the south. In the area of known potash occurrence in Manitoba, the thickness of the Esterhazy Member averages between 5.6 m in the northern areas and 2 m at its southernmost extent.

The Esterhazy Member in Manitoba is comparable in thickness, grade and insoluble mineral and carnallite content to potash deposits at Rocanville and Esterhazy in southeastern Saskatchewan. Accordingly, technical aspects related to mine development in Manitoba are anticipated to be similar to those experienced in neighbouring Saskatchewan. The headframe of the Rocanville mine is located less than 5 km west of the Saskatchewan-Manitoba border.

Potash occurrences

Russell-McAuley area

The potash deposits in the Russell-McAuley area are located between townships 14 and 21, ranges 27 and 29W1, and are the most explored area for potash in the province. Within the project area, 41 potash/stratigraphic test drillholes penetrate the Prairie Evaporite, of which 30 have core through the potash beds. Additionally, there is a good cross-section of 2-D seismic lines and two 3-D seismic blocks. Depths to the top of the Prairie Evaporite in this area range from 785 to 1050 m. The isopach of the formation varies due to proximity to the dissolution edge but can measure up to 139 m thick (as measured by seismic in Assessment File 74426, Manitoba Mineral Resources, Winnipeg). The eastern dissolution edge in this area is well defined by 2-D seismic surveys (Figure GS-8-1).

The deposits in the Russell-McAuley area are the only potash deposits in Manitoba potentially amenable to conventional underground mining methods. Although the depth and grade of the deposits are comparable to those at Rocanville and Esterhazy in Saskatchewan, challenges to mine development include proximity of the area to the salt-dissolution edge (Figure GS-8-1); commensurate eastward decrease of the salt-back thickness (i.e., thickness of the salt between the top of the Esterhazy Member and the base of the Second Red Bed Member of the Dawson Bay Formation; Figure GS-8-5). Challenges that are not unique to Manitoba include geological anomalies, such as underlying Winnipegosis Formation reefs, salt-collapse structures and mineralogical impurities (insoluble minerals and carnallite). These challenges are demonstrated in Figure GS-8-6, where Winnipegosis

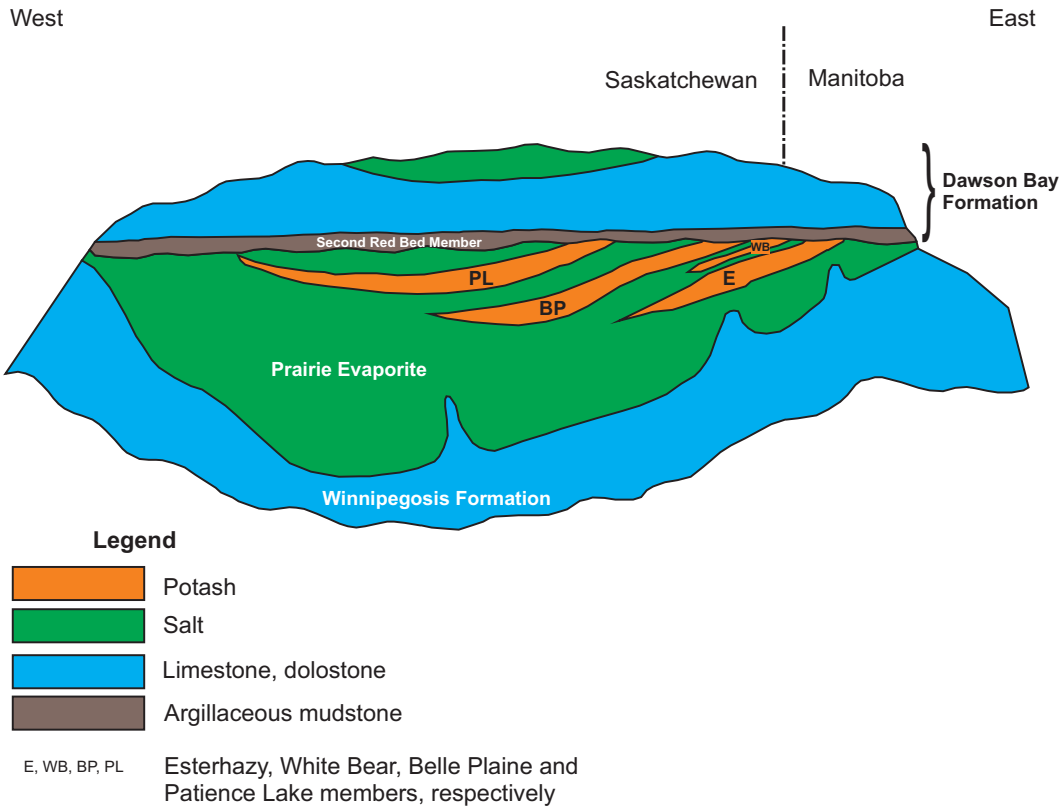

Figure GS-8-4: *Idealized east–west cross-section through the Prairie Evaporite and adjacent formations (modified from Bannatyne, 1983; Fuzesy, 1984).*

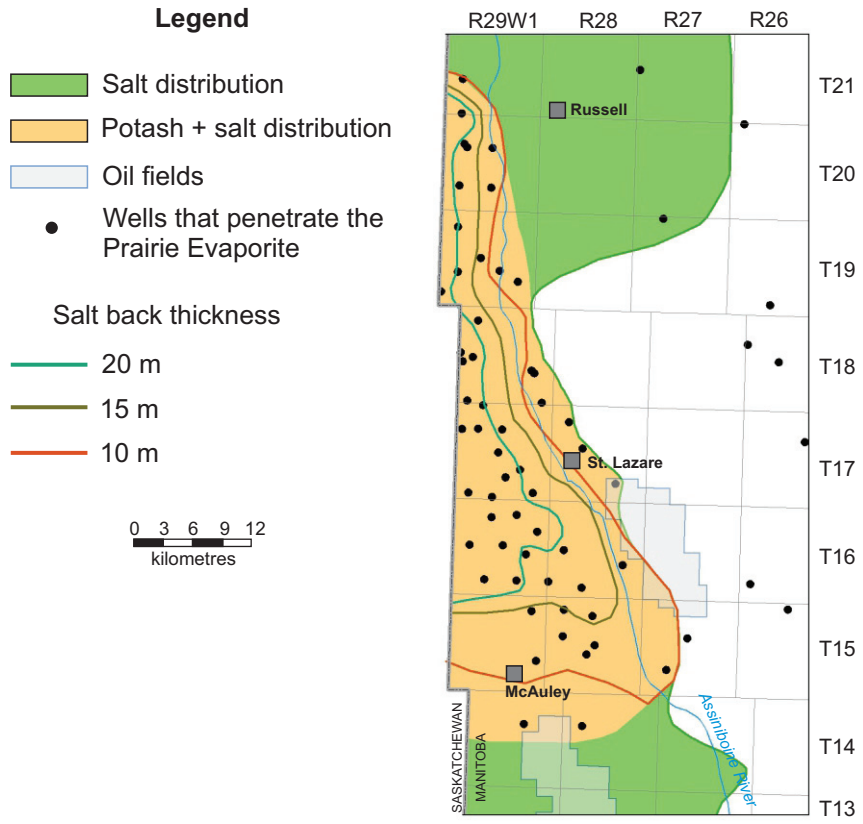

Figure GS-8-5: *Salt-back thickness in the Prairie Evaporite above the Esterhazy Member in the Russell-McAuley area.*

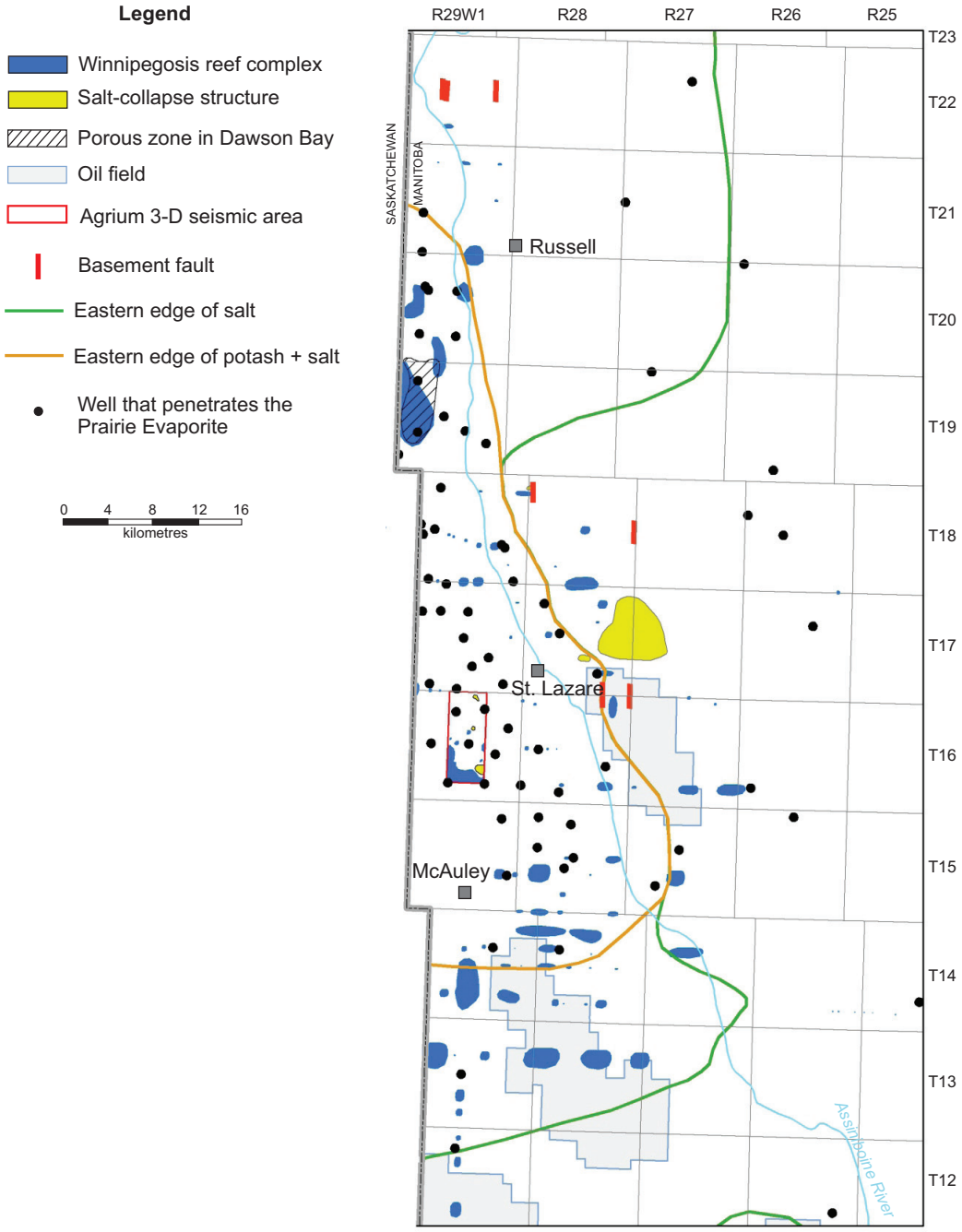

Figure GS-8-6: *Compilation showing the location and size of Winnipegosis reefs, a salt-collapse structure and basement faults, as identified by 2-D and 3-D seismic surveys. Information compiled from Assessment File 74426 and Gendzwill (unpublished report, 1986).*

reefs and a salt-collapse structure are easily imaged on seismic profiles.

The Russell-McAuley area has proven petroleum potential, with a small four-well oil pool centred on 4-22-16-29W1 (Melita A pool) and a single-well pool at 6-17-16-29W1 (Melita B pool), both of which produced a limited volume of oil from the Jurassic Melita Formation over a very short period of time. The Melita B pool was abandoned after reporting only one month of marginal production; although the Melita A pool is not yet abandoned, it has had no reported oil production since 1998. Oil accumulations in deeper horizons are highly likely, particularly in the Mississippian Bakken Formation, because the Birdtail Field is located immediately east of the study area, with the potash + salt edge occurring within the oil field. It should be noted that there are a few wells producing from the Bakken Formation nearby to the west in Saskatchewan. A detailed study of the Bakken and

Torquay formations by Nicolas (2012) also supported the idea of potential economic oil accumulations within this area.

From a potash-resource perspective, the Russell-McAuley area can be subdivided into two blocks: a northern block, referred to as the Russell deposit; and a southern block, referred to as the St. Lazare deposit. The distinction between the two blocks reflects the extent of two long-standing potash dispositions held by competing companies. Both these deposits have been explored extensively for potash during the past 60 years, most intensely during periods of buoyant potash prices in the 1980s and again starting in 2005.

Russell deposit

The Russell deposit is located within townships 19 to 21, range 29W1 (Figure GS-8-1). The deposit has been explored for decades and has been the subject of several resource estimations and feasibility studies. Recent estimates indicate a mineral resource of 392 million tonnes with an average grade of 22.5% K_2O and a mining thickness of 2.74 m (ADM Consulting Ltd., unpublished report, 2009).

Thirteen drillholes have penetrated the Prairie Evaporite in this area, all of them encountering potash of the Esterhazy Member with ore grades over mineable widths. Seismic studies of the area have identified several structural anomalies where Winnipegosis reef complexes were found to affect the overlying formations; however, no major salt removal, such salt-collapse structures, was identified (Figure GS-8-6; Gendzwill, 1986). The proximity to the salt-dissolution edge causes the salt thickness to decrease quickly over a 3 km distance, causing a rapid decrease in the thickness of the overlying salt toward the east (Figure GS-8-5).

A compilation of Winnipegosis reef complexes, collapse structures and basement faults identified from 2-D seismic lines in the Russell-McAuley area was conducted by Western Potash Corp. (Figure GS-8-6; Assessment File 74662). The compilation was focused on the southern St. Lazare deposit (see below) but included four seismic lines across the northern half of the Russell deposit. Basement faulting and small Winnipegosis mound structures were identified in this in area. Identification of these features is critical in the assessment of the deposit, since they can introduce large volumes of water into a mining operation from the aquifers above (Manitoba aquifer) and below (Winnipegosis aquifer) the Prairie Evaporite. The 1986 seismic study (Gendzwill, 1986) identified five Winnipegosis reef complexes of varying sizes and a large porous zone within the Dawson Bay Formation.

St. Lazare deposit

The St. Lazare deposit is located immediately south of the Russell deposit within townships 14 to 18, ranges 28 to 29W1 (Figure GS-8-1). A historical resource estimated for this deposit by Bannatyne (1983) was 650 million tonnes of sylvite with average grade of 20.9% K_2O, a 16% cut off grade and a mining thickness of 2.44 m. The potash grade is comparable and reflects the eastward continuation of the Rocanville mine deposit. This deposit is continuous to the north, where it becomes the Russell deposit.

A 26.6 km^2 3-D seismic survey was conducted by Agrium Inc. in 2005 in the central portion of the property within township 16, range 29W1 to assess the geological conditions for potential future mining operations (Figure GS-8-6; Assessment File 74426). The structure on top of the Prairie Evaporite, as shown on the seismic survey, agrees with the expected regional dips and trends, with isopachs of 74–139 m. There were five geological anomalies identified within the surveyed area that reflect the loss of Hubbard salt, the presence of structural lows and amplitude anomalies on the Shell Lake Member, the presence of Winnipegosis mound complexes and the identification of three collapse structures (Figure GS-8-6; Assessment File 74426).

The Hubbard salt is absent in Manitoba, as shown on regional structure and isopach maps (TGI Williston Working Group, 2008a, b), but it may have been present in the past and has since been dissolved. The reasons for the Shell Lake Member anomalies are unclear, but they may be related to underlying small Winnipegosis reefs (based on data in Assessment File 74426). A large, broad platform reef is located in the southwestern corner of the seismic-survey area, with five smaller pinnacle reefs occurring in the southern half of the area. Three collapse structures were identified, one of which is directly related to a pinnacle reef (Figure GS-8-6).

In the St. Lazare deposit, the Western Potash Corp. 2-D seismic compilation (Assessment File 74426) identified several Winnipegosis reef complexes of varying sizes and shapes, as well as collapse structures and basement faults (Figure GS-8-6).

Daly-Sinclair area

The Daly-Sinclair area is located in townships 5 to 11, ranges 27 to 29W1, and is only defined by eight wells drilled deep enough to penetrate the Prairie Evaporite (Figure GS-8-1). This area is separated from the Russell-McAuley potash area by a broad area with no potash occurrences. This zone extends westward up to six townships into Saskatchewan. There are no cores of the Prairie Evaporite from this area, and the presence (or assumption) of potash is based only on geophysical well logs. The edge of the potash occurrence is based on these eight wells and is therefore not very accurate. The depth to the Prairie Evaporite is 1240 to <1520 m, with isopachs ranging between 120 and 13 m. The Esterhazy Member in this area has an average isopach of 7 m; however, since it is

only measured from geophysical logs, the accuracy of this isopach is questionable. Occurring too deep for a conventional underground mine, extraction of this potash could only be by solution mining. No potash-resource assessment has ever been done for this area.

This area is best known for its oil production. The Daly-Sinclair and Tilston fields directly overlie this potash deposit. Producing from the Mississippian Mission Canyon, Lodgepole and Bakken formations and the Devonian Torquay Formation, this area is one of the most prolific oil fields in Manitoba.

Pierson area

The potash occurrence in the Pierson area has been identified in only two wells (10-9-1-28W1 and 14-15-1-28W1), whose geophysical log signatures suggest the presence of thin potash beds <2 m thick at depths between 1630 and 1670 m (Figure GS-8-1). There are no Prairie Evaporite cores from this area and no resource assessment has ever been conducted. This potash occurrence is separated from the Daly-Sinclair deposit by another area with no potash occurrences; this deposit is likely connected to the potash deposit immediately to the south in North Dakota. The Pierson field occurs north of the known potash wells and produces from the Jurassic Amaranth Formation and the Mississippian Mission Canyon Formation.

Comparison to Saskatchewan potash deposits

Canada has 46% of global potash reserves and has the highest potash production of any country in the world (Natural Resources Canada, 2015), with mines in Saskatchewan and New Brunswick. Saskatchewan has the higher potash production and holds the largest resource. Saskatchewan's geological position in the centre and northern part of the Elk Point Basin means that the Prairie Evaporite covers most of the subsurface in the southern part of the province (Figure GS-8-2**)**. All four potash members occur in Saskatchewan, and three of them (Patience Lake, Belle Plaine and Esterhazy members) have been mined for potash (Fuzesy, 1984; Yang et al., 2009). The four potash beds have a combined area of 129 552 km^2 in Saskatchewan.

Potash has been mined continuously in Saskatchewan since 1962 (Fuzesy, 1984). The province has 10 operating mines, of which 8 are conventional underground mines and 2 are solution mines. The latter consist of a flooded underground mine at Patience Lake, now operating as a solution mine, and a solution mine at Belle Plaine. Six mines in the area near Saskatoon (Allan, Cory, Lanigan, Patience Lake, Vanscoy and Colonsay) produce from the Patience Lake Member. Three mines in the southeastern part of the province close to Manitoba-Saskatchewan border (Rocanville and Esterhazy K1 and K2) produce from the Esterhazy Member. The Belle Plaine solution mine produces from all members.

The presence of three potash beds over a large area gives Saskatchewan very large potash reserves and therefore a great economic advantage. By conservative estimates, the province could supply world demand at current levels for several hundred years. The PCS Rocanville mine alone has proven and probable reserves of 481 million tonnes of recoverable ore at an average grade of 23.5% K_2O, with a remaining mine life of 79 years; the 2013 annual production was 1.99 million tonnes KCl (Northern Miner, 2014). By comparison, a resource assessment for the St. Lazare deposit indicates that it could support a mine producing 2.0 million tonnes KCl per year for more than 20 years (Bannatyne, 1983).

Economic considerations

Potassium extracted from potash deposits is used dominantly in the fertilizer industry to help increase crop yields. With growing world population and a steady increase in the demand for fertilizer, the potash market will be stable for many years. The potash deposits in Manitoba, although less extensive than those in Saskatchewan, are of sufficient size and grade to attract potential development. The deposits in the Russell-McAuley area are of excellent grade and at favourable depth, so they may be mined using conventional underground methods, assuming acceptable geological conditions. A potash mine in southwestern Manitoba would provide considerable economic development opportunities for the region and the province.

Acknowledgments

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