Beyond oil: mineral potential within and below Manitoba's oil fields

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Manitoba

POTASH

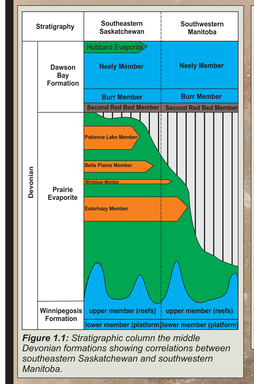

Figure 1.1: Stratigraphic column the middle Devonian formations showing correlations between southeastern Saskatchewan and southwestern Manitoba.

1.1 Introduction

The Prairie Evaporite is a thick Denonian-aged evaporitic sequence dominantly consisting of halite and anhydrite. It includes four potash-bearing members with only the Esterhazy and White Bear members extending into Manitoba (**Figure 1.1**). The Esterhazy Member is the only potash bed in Manitoba explored with sufficient thickness and grade to sustain potentially economic potash mining. The ore grade and tonnages measured in Manitoba's Esterhazy Member are comparable to nearby, active, long-lived potash mines in Saskatchewan. Nearby mines include Nutrien's (fomerly Potash Corporation of Saskatchewan, PCS) Rocanville mine and The Mosaic Company's Esterhazy K1 and K2 mines.

The known area of potash occurrence in Manitoba can be subdivided into three subareas that are separated from the others by broad areas with no potash occurrence in the Prairie Evaporite (**Figure 1.2**). These areas total approximately 2,247 km^2 of known, potentially mineable, potash occurrences.

1) the Russell-McAuley area, covering townships14 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.

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.

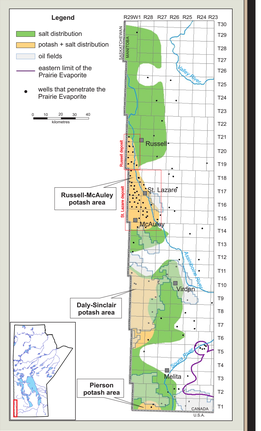

Figure 1.2: Map of southwestern Manitoba showing the distribution of the salt and potash + salt, oil fields and wells that penetrate the Prairie Evaporite. The three mains areas of potash occurrence are shown, as are the northern (Russell deposit) and southern (St. Lazare deposit) blocks of the Russell-McAuley area. The salt distribution edge is equivalent to the eastern limit of the salt and potash + salt distribution areas. (from Nicolas, 2015)

1.2 Russell-McAuley Area

The potash deposits in the Russell-McAuley area are located between townships 14 and 21, ranges 27 and 29W1 (**Figure 1.2**), and are the most explored area for potash in the province. The isopach of the formation varies due to proximity to the dissolution edge but can measure up to 139 m thick.

The deposits in the Russell-McAuley area are the only potash deposits in Manitoba potentially amenable to conventional underground mining methods, however are also excellent candidates for solution mining. This potash resource has been historically subdivided into two blocks: a northern block, referred to as the Russell deposit; and a southern block, referred to as the St. Lazare deposit (**Figure 1.3**). Both deposits are continuous into one another, the distinction between the two blocks simply reflects the extent of two long-standing potash dispositions held by past competing companies.

1.3 Potash Resource

Formal mineral resource estimates have been prepared for the Russell deposit, most recently in 2009. A historical resource estimate for the St. Lazare deposit was prepared in 1983. **Table 1.1** summarizes the estimated resources for both the Russell and St. Lazare deposits assuming conventional underground mining operations. The Russell-McAuley area has a robust resource potential for a long term, minimum 20 year, secure supply, at a rate of 2 Mt/y KCl, or higher.

Table 1.1: Mineral resource estimates for the Russell and McAuley areas in southwestern Manitoba.

Area	Million tonnes[1]	Average grade (% K_2O)
Russell deposit[2]	392	22.5
St. Lazare deposit[3]	650	20.9

[1] BHP Billiton reports from ADM Consulting Ltd. and AMEC Americas Ltd. (2009)

[2] Bannatyne (1983), 16% cut off grade

[3] Neither of the resource estimates has been reported using the definition standards of the Canadian Institute of Mining, Metallurgy and Petroleum and, therefore, do not meet the reporting requirements of Canadian National Instrument 43-101.

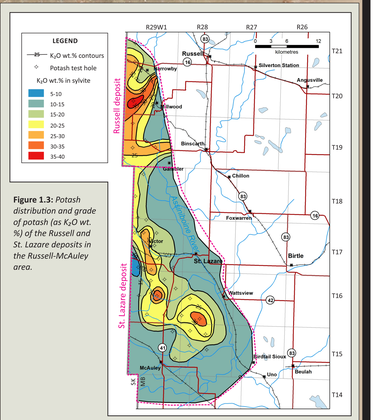

Figure 1.3: *Potash distribution and grade of potash (as K_2O wt. %) of the Russell and St. Lazare deposits in the Russell-McAuley area.*

LITHIUM BRINES

2.1 Introduction

Saline groundwater in continental sedimentary basins are generated from evaporitic concentration and/or halite dissolution, where the former is a primary process and the latter is a secondary (diagenetic) process. Both these mechanisms provide opportunities for trace elements to accumulate, potentially reaching economic concentrations.

Production of lithium from these deep saline waters in continental sedimentary basins is currently being examined by industry as a potential cost-effective source of this element. In Manitoba, the mineral potential of brines remains largely under explored and little understood.

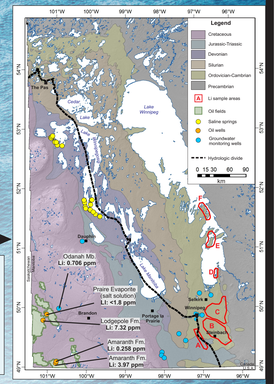

Figure 2.1: Regional geological map with digital elevation model of southern Manitoba showing hydrological divide (follows the 2000 mg/L total dissolved solids contour) with the location of saline springs and freshwater recharge regions from Grasby and Betcher (2002); areas A through F group multiple water sampling points (data from Ferguson et al., 2005); location of oil wells and groundwater monitoring wells with Li analyses are shown. Only wells with lithium values above 0.2 ppm are highlighted with their measured concentrations labelled. Digital elevation model from United States Geological Survey (2002).

2.2 Manitoba Groundwater

Southern Manitoba has a complex groundwater aquifer system, with salinities ranging from brines (> 35,000 mg/L TDS) in the deeper aquifers to freshwater (<2,000 mg/L TDS) in the shallower and eastern aquifers. Freshwater and saline groundwaters are separated by a hydrologic divide (**Figure 2.1**)

Manitoba's oil and gas operations produce large quantities of these brines as produced waste water, which contain a wide range of trace elements. These "petro-brines", as well as untapped deeper brines, are potential sources of lithium, along with other commonly associated metals, such as bromine and iodine.

Although very limited results indicate that the lithium concentrations in Manitoba's brines are low (**Figure 2.1 and 3.2**; Nicolas, 2017; Nicolas and Grasby, 2018), extrapolation of better, more comprehensive results from Saskatchewan, listed in **Figure 3.2**, suggests that there is potential for lithium concentrations to be higher than currently recorded in Manitoba. Shallower brines and saline waters measured from the groundwater monitoring wells have slightly lower values for lithium, compared with the brines derived from deep oil wells. Freshwater-dominated Cambro-Ordovician aquifers along the eastern erosional edge of the Williston Basin have extremely low lithium concentrations.

2.3 Economic Considerations

Saltwater production and disposal from oil wells is a constant issue for the petroleum industry and is one of the dominant reasons for marginal well abandonment. The mineral potential of these brines may serve as an excellent economic opportunity for the operators to improve their profits and extend the life of marginal oil wells, taking advantage of the array of infrastructure already in place for these operations.

Middle Devonian-aged horizons have the best potential for high lithium values, as shown in Saskatchewan's Duperow Formation and Alberts Leduc Formation in the Fox Creek area (**Figure 3.2**). In Manitoba, Li-targeted exploration is required in the horizons below the deepest oil production in Manitoba for proper evaluation of this potential resource.

HELIUM

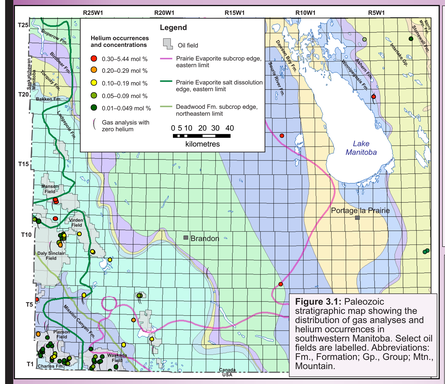

Figure 3.1: Paleozoic stratigraphic map showing the distribution of gas analyses and helium occurrences in southwestern Manitoba. Select oil fields are labelled. Abbreviations: Fm., Formation; Gp., Group; Mtn., Mountain.

3.1 Introduction

The special properties of helium, the second lightest element, make it the ideal element for a multitude of uses. Increased demand and a decreased US supply have resulted in an increase in the price of helium, sparking a renewed interest to explore for helium in politically stable countries like Canada.

Helium is formed primarily by the radioactive decay of uranium- and thorium-bearing minerals in crystalline Precambrian basement rocks and in detrital sedimentary rocks such as shale. Economic concentrations (0.3% by volume or 0.3 mol % assuming ideal gas conditions) of helium can be produced as a by-product of oil and gas production operations and is referred to as crude helium.

3.2 Exploration

Southwestern Manitoba is geologically well positioned for economic helium deposits within its sedimentary strata. A search of oil and gas technical well files identified 69 wells with recorded helium occurrences (**Figure 3.1**). Of those occurrences, six wells had helium values above the economic cut-off of 0.30 mol % He with ranges from 0.30 to 2.00 mol % He (**Figure 3.2**; Nicolas, 2018).

In Manitoba, the first exploration for helium was conducted near the community of Lundar, on the east side of Lake Manitoba. In 1962, Hemisphere Helium Corporation drilled two wells where they collected four fluid samples that returned helium concentrations of 0.2–2.0 mol % from the lower sandstone member of the Winnipeg Formation (Hemisphere Helium Corporation Ltd., 1962a, b).

The best targets in Manitoba are the Bakken–Torquay formations interval, which benefits from the overlying 'hot' shales, and the Deadwood–lower Winnipeg formations interval, which sits directly over the Precambrian rocks where basement structural features can create trapping conditions (Nicolas, 2018).

3.3 Economic Considerations

Helium can be produced with oil and gas using infrastructure already in place and provided by the petroleum industry. The helium potential within the oil and gas produced may serve as a good economic opportunity for operators to improve profits from these wells and may help to extend the life of marginal oil wells.

However, strategic deep exploratory drilling along deep structures and faults into the basal clastic horizons of the Winnipeg and Deadwood formations overlying the Precambrian basement may provide the most prolific accumulations (Nicolas, 2018).

Williston Basin lithium concentration (excludes MB)	Manitoba Lithium concentration	Manitoba Lithium occurrences	ERA	PERIOD	FORMATION	Manitoba Helium occurrences	Manitoba Max He conc. (mol %)	Manitoba Sealing horizons	Williston Basin helium concentration (excludes MB)
			CENOZOIC	QUATERNARY	(RECENT SEDIMENTS)				
					GLACIAL DRIFT				
				TERTIARY					
					TURTLE MOUNTAIN				
			MESOZOIC	CRETACEOUS	BOISSEVAIN				
					PIERRE SHALE				
					CARLILE				
					FAVEL				0.30 – 7.26% (K)[1]
					ASHVILLE				
					SWAN RIVER				
				JURASSIC	SUCCESS				
					WASKADA				
					MELITA				
					RESTON				
	0.706 – 1.18 ppm (Od)	Li		TRIASSIC	AMARANTH	He	0.21% (LA)		0.30 – 0.78% (JR)[1]
			PALEOZOIC	PERMIAN					
				PENNSYL-VANIAN	ST. MARTIN COMPLEX				
	41 ppm (Fb)[3]			MISSISSIPPIAN	CHARLES				
	25 – 32 ppm (Mb)[3]				KISBEY				
	1.3 ppm (Md)[4]				MISSION CANYON	He	0.30% (MC3) 0.83% (MC1)		0.31 – 0.39% (M)[1]
	7.32 ppm (Lp)	Li			LODGEPOLE	He	0.22% (WI)		
	14 ppm (Bk)[3]				BAKKEN	He	1.30%		
	28 – 32.4 ppm (Ty)[5]				BIG VALLEY				
	18 – 59 ppm (Bb)[3]				TORQUAY	He	1.30%		
	36 – 190 ppm (Dp)[3,4]	*Equivalent interval of lithium-rich brine in Fox Creek, AB (140 ppm Li)*		DEVONIAN	BIRDBEAR				
					DUPEROW	He	0.20%		0.40 – 0.69% (Sr-Db)[1]
					SOURIS RIVER				
					DAWSON BAY	He	0.04%		
	<1.8 ppm (Pe)	Li			PRAIRIE EVAPORITE				
	12 – 54 ppm (Ws)[3]				WINNIPEGOSIS				
					ELM POINT				
	0.488 – 1.4 ppm (OS)	Li			ASHERN				
				SILURIAN	INTERLAKE GROUP				
				ORDOVICIAN	STONEWALL				0.28% (Sm)[1]
					STONY MOUNTAIN				0.10 – 2.45% (Rr)[1]
	9 – 55 ppm (Rr)[3]	0.780 – 3.890 ppm (Rr)	Li		RED RIVER	He	0.20%		0.18 – 1.39% (Wg)[1]
		0.857 – 3.440 ppm (Wg)	Li		WINNIPEG	He	2.0% (LW)		0.09 – 0.37% (Wg)[2]
									0.90 – 2.03% (Dw)[1]
				CAMBRIAN	DEADWOOD				0.07 – 0.46% (Dw)[2]
	0.761 – 3.970 ppm (LA)	Li		PRECAMBRIAN		He	2.0%		

Figure 3.2: Stratigraphic column of southwestern Manitoba showing lithium and helium occurrences (Nicolas 2017; Nicolas and Grasby 2018; Nicolas, 2018), as ranges of values and as maximum helium concentrations reported for that interval (for helium in Manitoba only); lithium concentrations are measured from brines, with the exception of the one from the Prairie Evaporite, which is measured from the rock salt; the abbreviations in the parentheses indicates the stratigraphic unit in which the occurrence was measured, if known; and known potential sealing horizons for helium. Red text indicates values equal to or above 0.30 mol % He and 80 ppm Li. Green oil droplets indicate oil producing horizons in Manitoba.

Abbreviations: Bb, Birdbear Formation; Bk, Bakken Formation; Dp, Duperow Formation; Fb, Frobisher Beds; LA, lower Amaranth Formation; Lp, Lodgepole Formation; LW, lower Winnipeg Formation; Mb, Midale Beds; Md, Madison Group; MC1, MC-1 Member; MC3, MC-3 Member; Od, Odanah Member; OS, Ordo-Silurian; Pe, Prairie Evaporite; Rr, Red River Formation; Ty, Torquay Formation; Wg, Winnipeg Formation; Wt, Whitewater Lake Member; Ws, Winnipegosis Formation.

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