

## Stratigraphy and distribution of the potash-bearing members of the Devonian Prairie Evaporite, southwestern Manitoba (parts of NTS 62F, K)

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### In Brief:

- New mapping of potash has increased exploration space
- Prairie Evaporite has three separate potash beds extending into Manitoba from the west

### Citation:

Nicolas, M.P.B. and Yang, C. 2022: Stratigraphy and distribution of the potash-bearing members of the Devonian Prairie Evaporite, southwestern Manitoba (parts of NTS 62F, K); in Report of Activities 2022, Manitoba Natural Resources and Northern Development, Manitoba Geological Survey, p. 87–95.

### Summary

In Manitoba, the Devonian Prairie Evaporite is a thick sequence of evaporitic beds with three potash members—Esterhazy, White Bear and Belle Plaine—near the top of the formation. Of these three, the White Bear Member is the most extensive, followed by the Esterhazy Member, then the Belle Plaine Member. The Esterhazy Member hosts Manitoba's first proposed potash mine, located near the town of Russell.

New mapping of the potash distribution has increased the potash exploration area from previous potash distribution maps, with extensions north up to Twp. 25 and farther east to Rge. 27, W 1<sup>st</sup> Mer. In addition, new mapping of the zero edge of total salt distribution in the Manson and Virden oil fields supports the hypothesis that salt dissolution and collapse strongly effected oil pool formation and development in those areas.

### Introduction

The Devonian Prairie Evaporite is a thick sequence of evaporitic beds, dominantly halite beds with sylvite- and carnallite-rich beds, with anhydrite and minor clay and dolostone interbeds. The formation overlies the reefal and platform carbonates of the Winnipegosis Formation and underlies the platform carbonates of the Dawson Bay Formation. In Manitoba, the Prairie Evaporite stratigraphy, from the bottom up, includes the anhydritic basal Winnipegosis transitional beds, the Shell Lake anhydrite and the three potash members—Esterhazy, White Bear and Belle Plaine (Figure GS2022-10-1). Each of these members is separated by thick, unnamed halite beds. Through recent cross-border collaborations between the geological surveys of Manitoba and Saskatchewan, the extension of the Belle Plaine Member into Manitoba was confirmed. Bannatyne (1983), with a follow-up by Nicolas (2015), provides a detailed description of the geology of the potash beds in Manitoba and their economic prospectivity.

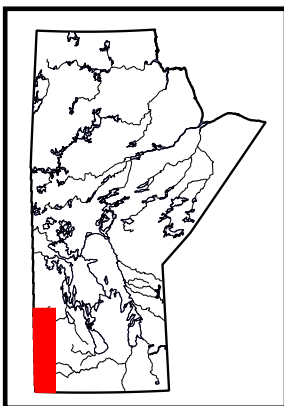
This report outlines the distribution of the three individual potash members, and includes revised mapping of potash distribution and the zero edge of salt distribution in Manitoba.

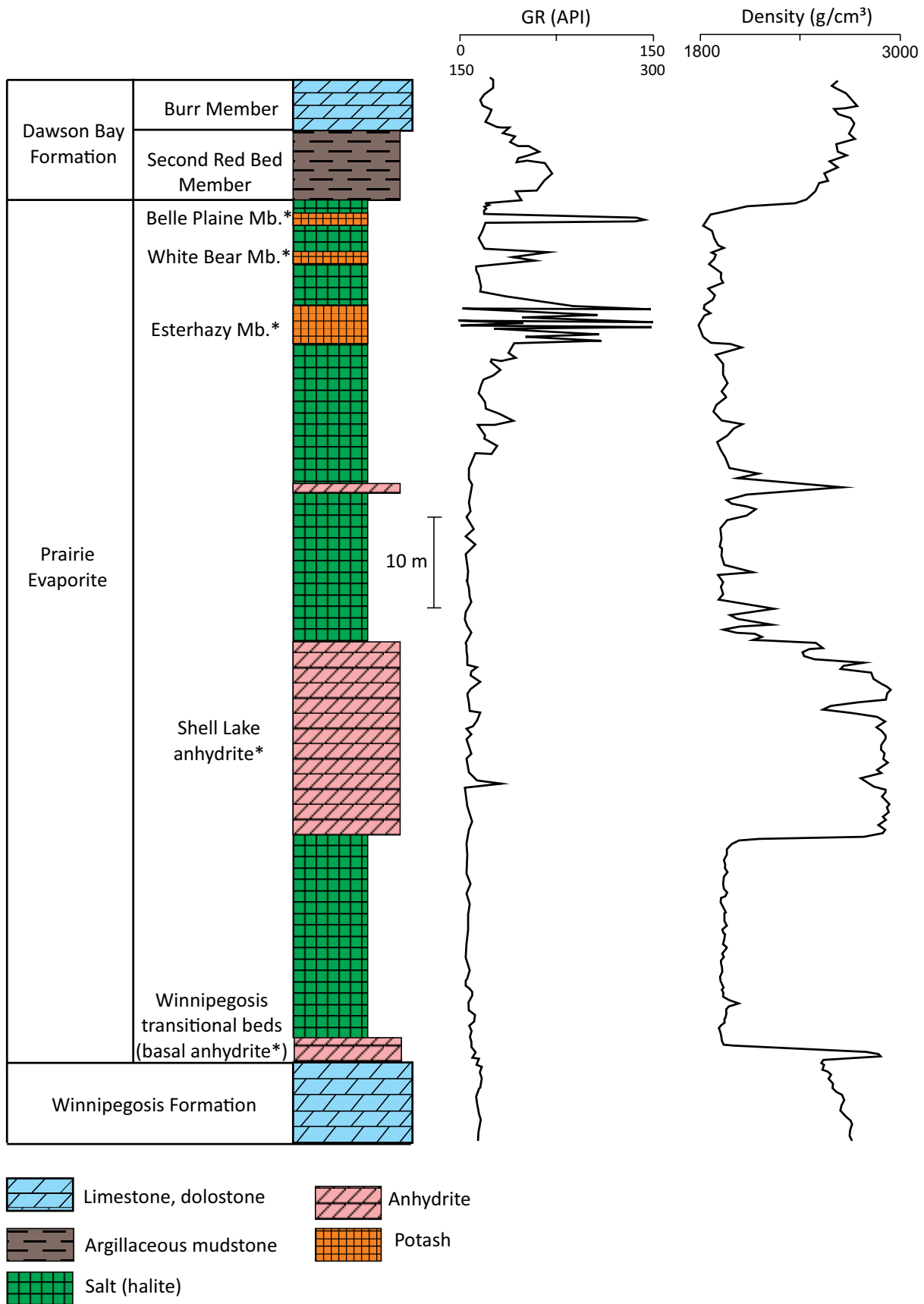
### Potash exploration and development

Bannatyne (1960) completed the earliest study on the halite and potash deposits in the Prairie Evaporite, just as economic potash deposits in Saskatchewan were discovered and exploration efforts began in Manitoba. Bannatyne (1983) provided the first look at the economics and potash grades of the St. Lazare deposit. Nicolas (2015, 2019) provided an update on potash distribution and the first look at the grade distribution of the Russell deposit (Figure GS2022-10-2). There are three known areas of potash occurrences in Manitoba: 1) Russell-McAuley, 2) Daly-Sinclair and 3) Pierson (Figure GS2022-10-2).

Recently, there has been renewed interest in the Russell deposit, with the drilling of the first pair of horizontal potash production wells by Potash and Agri Development Corporation of Manitoba Ltd. (PADCOM) in L.S. 12, Sec. 21, Twp. 20, Rge. 29 W 1<sup>st</sup> Mer. (abbreviated 12-21-20-29W1; Figure GS2022-10-3), oil and gas well licences 11642 and 11643 (Manitoba Natural Resources and Resource Development, Winnipeg). PADCOM's Environmental Act licence no. 3375 (Manitoba Environment, Climate and Parks, Winnipeg) for this development indicates a selective dissolution process will be used to extract the potash, leaving halite in the ground. At the time of writing, production had not yet started.

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**Figure GS2022-10-1:** Schematic stratigraphic column of the Devonian Prairie Evaporite in Manitoba, with a representative composite gamma-ray and bulk density downhole geophysical log. The vertical scale is approximate. The asterisk (\*) indicates beds that are not always present. Abbreviations: GR, gamma ray; Mb., Member.

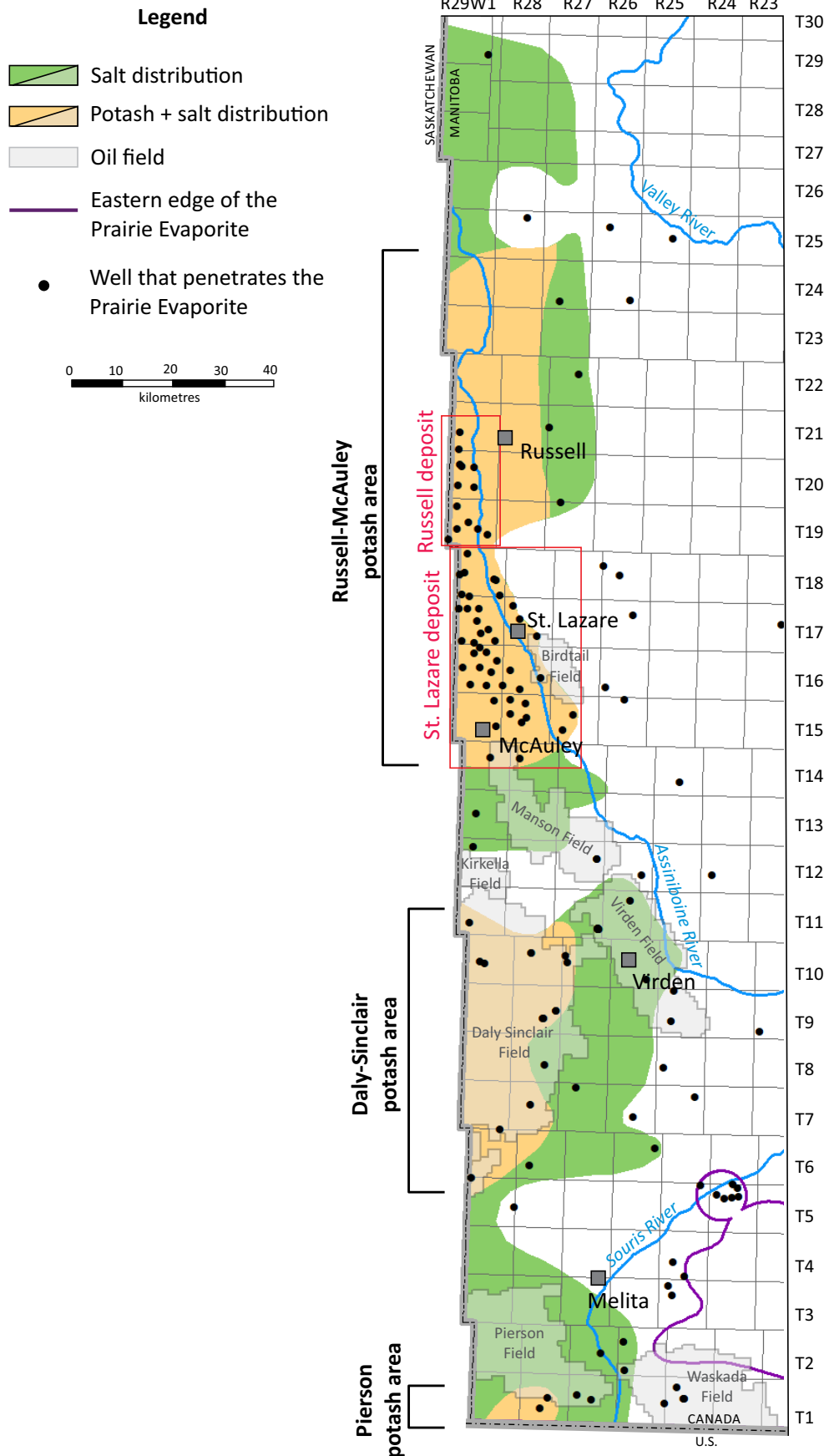
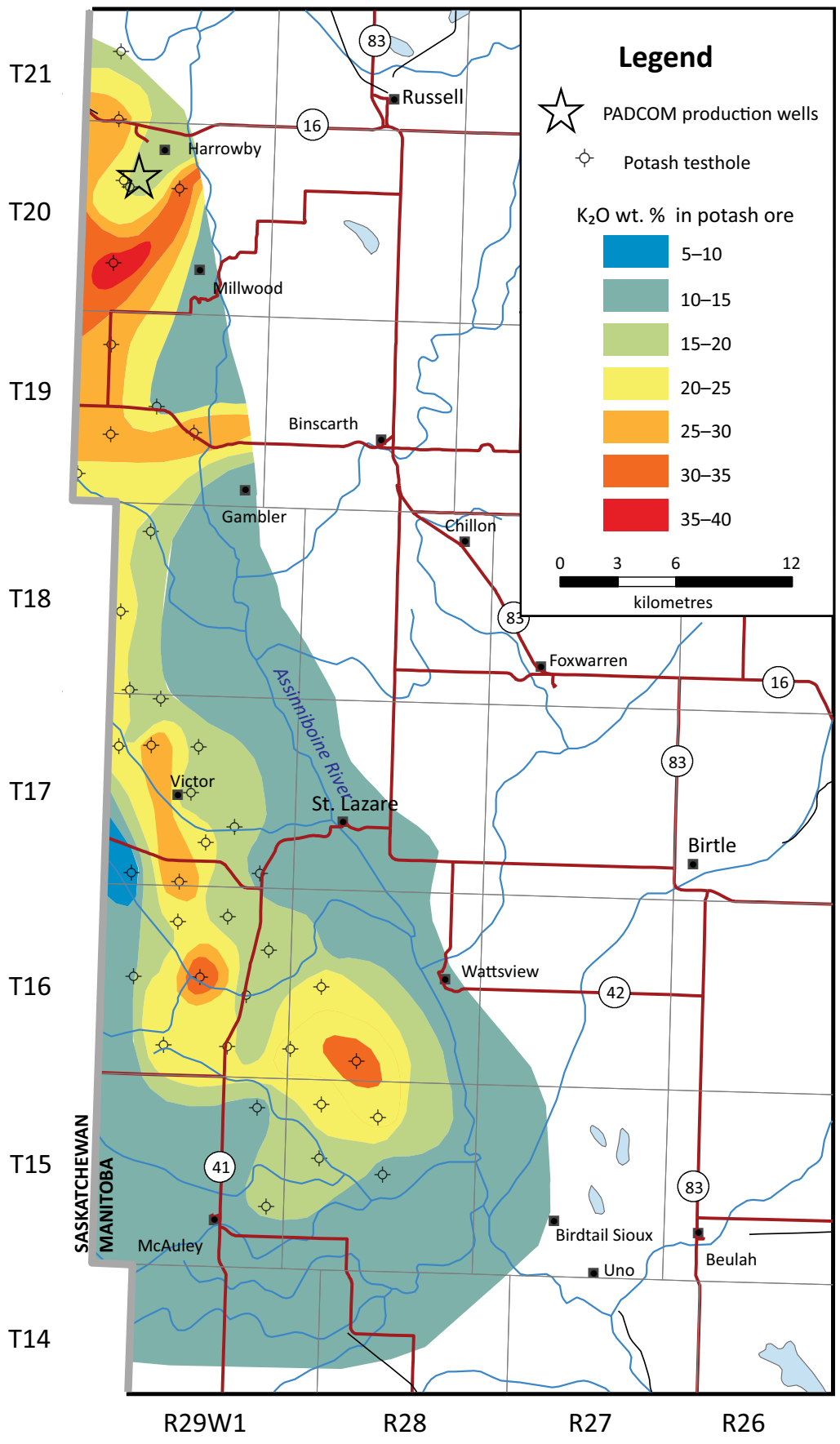


Figure GS2022-10-2: Distribution of salt, potash + salt, oil fields, and wells that penetrate the Prairie Evaporite in southwestern Manitoba.



**Figure GS2022-10-3:** Potash distribution and K<sub>2</sub>O wt. % in potash ore (sylvinitic) calculated as a weighted average over the best 2.44 m of ore of the Russell and St. Lazare deposits in the Russell-McAuley potash area, southwestern Manitoba (modified from Nicolas, 2019).

## Stratigraphy and potash distribution

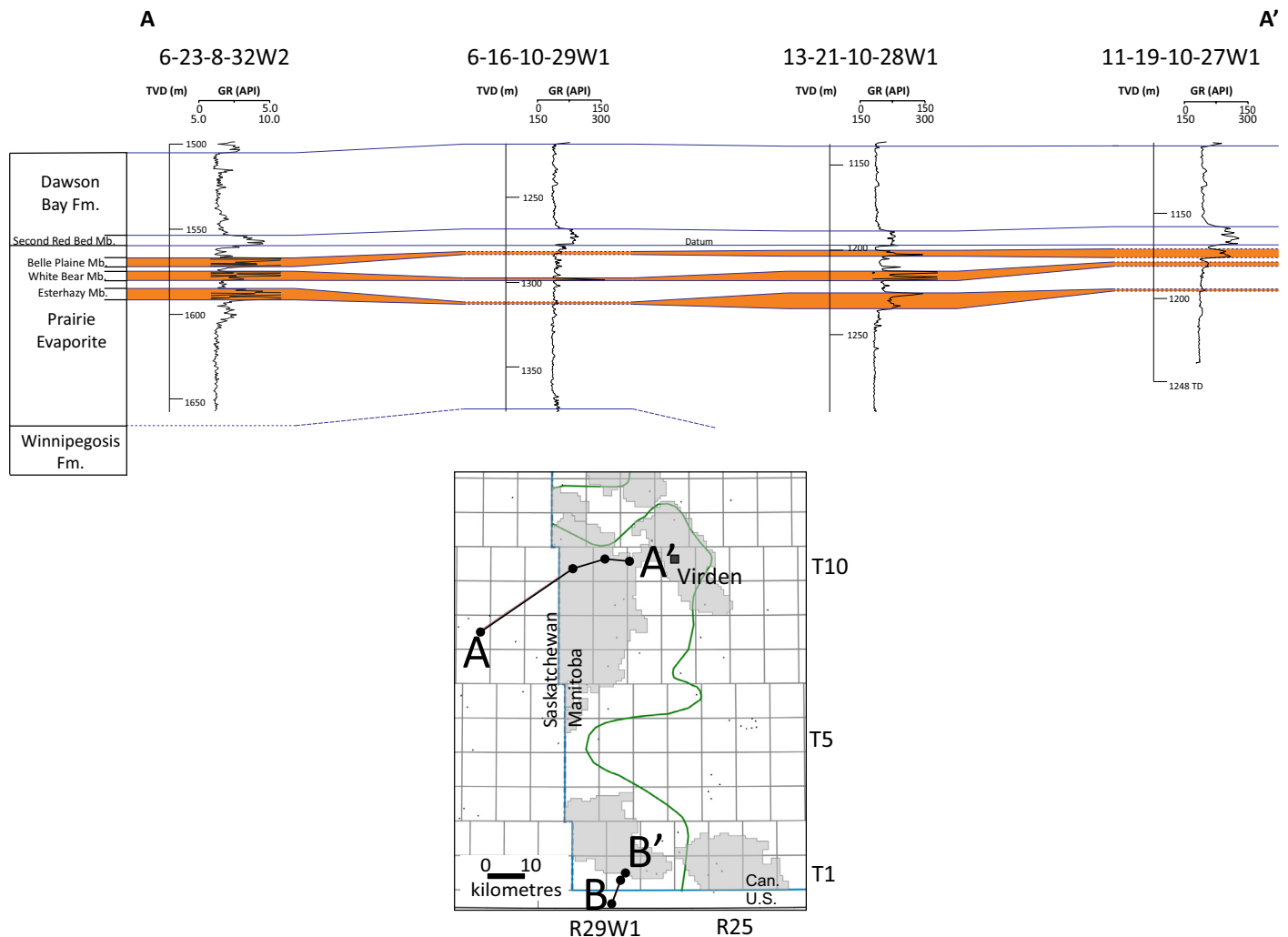
Detailed mapping of potash in Manitoba by the Manitoba Geological Survey and industry was generally focused on the northern deposits of the Russell-McAuley potash area, due to historical exploration being confined to those areas. Previous potash distribution mapping was restricted to areas of potash confirmed from testholes, which in turn, restricted the exploration area evaluated by companies. Bannatyne (1983) formally identified and confirmed the White Bear and Esterhazy members in southwestern Manitoba. Bannatyne (1983) suspected the presence of the Belle Plaine Member in two wells in the Daly-Sinclair potash area (Figure GS2022-10-2). Through new correlations and interpretive mapping, the White Bear Member now has the most expansive distribution in Manitoba, followed by the Esterhazy Member. The Belle Plaine Member is confirmed to extend into Manitoba more than originally speculated.

### Belle Plaine Member

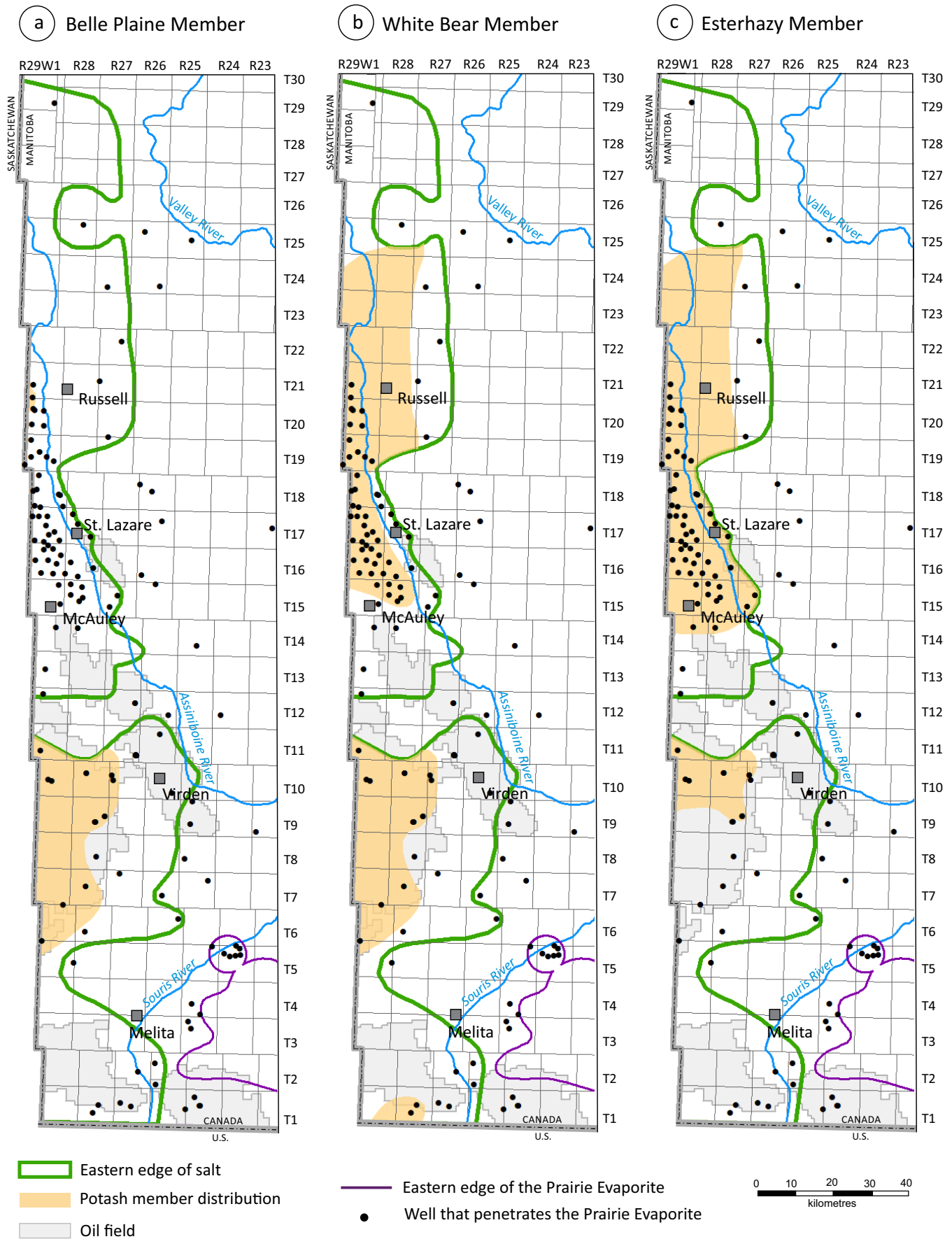
The stratigraphy of the Prairie Evaporite in Manitoba is now revised to include the Belle Plaine Member. Yang et al. (2018)

mapped the distribution of the potash members in Saskatchewan, providing updated zero-edge mapping of the Patience Lake, Belle Plaine and Esterhazy members up to the Manitoba border; these maps incorporated new off-confidential data points from potash test wells. Using these maps and interprovincial cross-sections, the continuity of the Belle Plaine Member into Manitoba was confirmed (Figure GS2022-10-4). In the Daly-Sinclair potash area, the Belle Plaine Member is the dominant potash bed, whereas in the Russell-McAuley potash area, it is restricted to a small area in Twp. 20 and 21, Rge. 29W1, near the Saskatchewan border. The distribution of the Belle Plaine Member is shown in Figure GS2022-10-5a.

The southwest to northeast cross-section A–A' in Figure GS2022-10-4 shows the distribution and preservation of three distinct potash members into Manitoba. The well at 6-16-10-29W1 shows the potash beds are locally thinner, with weak gamma-ray signatures in comparison to the other wells. This may be the result of localized complete salt dissolution, evident in a nearby well at 9-17-10-29W1; the resulting collapse and dissolution affects are slightly overprinted in the 6-16-10-29W1 well. In



**Figure GS2022-10-4:** Southwest to northeast cross-section A–A' from Saskatchewan to Daly-Sinclair potash area, southwestern Manitoba. Datum is top of Prairie Evaporite. Inset map shows the location of the cross-section and the eastern edge of salt distribution (green line). Abbreviations: 6-23-8-32W2, well at L.S. 6, Sec. 23, Twp. 8, Rge. 32, W 2<sup>nd</sup> Mer.; Fm., Formation; GR, gamma ray; Mb., Member; TD, total depth; TVD, true vertical depth.



**Figure GS2022-10-5: Distribution of the individual potash members in southwestern Manitoba: a) Belle Plaine Member, b) White Bear Member, c) Esterhazy Member.**

the well at 11-19-10-27W1, the gamma-ray signature only suggests a very thin Esterhazy Member, alternatively, this signature may represent a remnant or clay seam extension of the member as it approaches the zero edge of the member.

### **White Bear Member**

In wells where all three potash members are not present, it can be difficult to identify which potash member is present. This is exemplified in the south to north cross-section B–B', extending from North Dakota into the Pierson potash area of Manitoba (Figure GS2022-10-6), which uses the northeasternmost well from Kruger (2014) as the southernmost well in the cross-section. Mapping by Kruger (2014) suggests the potash member that extends into Manitoba's Pierson potash area is the White Bear Member, which is further supported by Bannatyne's (1983) mapping. Mapping and cross-border correlations from Saskatchewan are nonconclusive on the stratigraphic assignment of this potash member. The White Bear Member has a wider distribution on the United States side of the basin. In North Dakota, it is the most expansive of the potash-bearing members (Kruger, 2014). The same can be said for Manitoba, since most of the potash-bearing wells in Manitoba include the White Bear Member (Figure GS2022-10-5b), with the exception of a few wells nearing the zero edge of the potash distribution in the northern area. The White Bear Member in Saskatchewan has attracted less attention because of its lower ore grade, thinner thickness and poorer continuity compared to the other three economic potash members. The White Bear Member was mapped in Saskatchewan by Yang et al. (2009), but not updated in the later maps of Yang and Love (2015) and Yang et al. (2018). Figure GS2022-10-5b, cross-sections in Figure GS2022-10-6 and Figure GS2022-10-7 show the best estimation of the extent of the White Bear Member in Manitoba, based on current information.

### **Esterhazy Member**

The Esterhazy Member occurs in both the northern extent of the Daly-Sinclair and the entire Russell-McAuley potash areas (Figure GS2022-10-5c). This member is the most cored and explored potash member in Manitoba, representing the eastward extension of Nutrien Ltd.'s Rocanville mine and The Mosaic Company's K1 and K2 mines near Esterhazy, Saskatchewan. This extension into Manitoba has known economic grades (Bannatyne, 1983; Nicolas, 2015) and is the location of PADCOM's proposed selective-solution mine (Figure GS2022-10-3).

The Esterhazy Member has a well-defined log signature in the northern deposits, due to its high gamma-ray signature (e.g., 4-36-15-29W1 in Figure GS2022-10-7) and  $K_2O$  grades (Figure GS2022-10-3). Correlation of this member in the northern deposits is straightforward and commonly occurs with the White Bear Member above, except when approaching the zero edge of the salt distribution. In the St. Lazare deposit, there is a thickening of the Prairie Evaporite section above the Esterhazy Mem-

ber, where there may be a thin localized remnant of Belle Plaine Member preserved in wells at 8-6-17-29W1 and 5-10-17-29W1. Localized preservation of the Belle Plaine Member is not unexpected in this area, as similar localized occurrences were mapped by Yang et al. (2018) in Twp. 17, Rge. 30W1 in Saskatchewan.

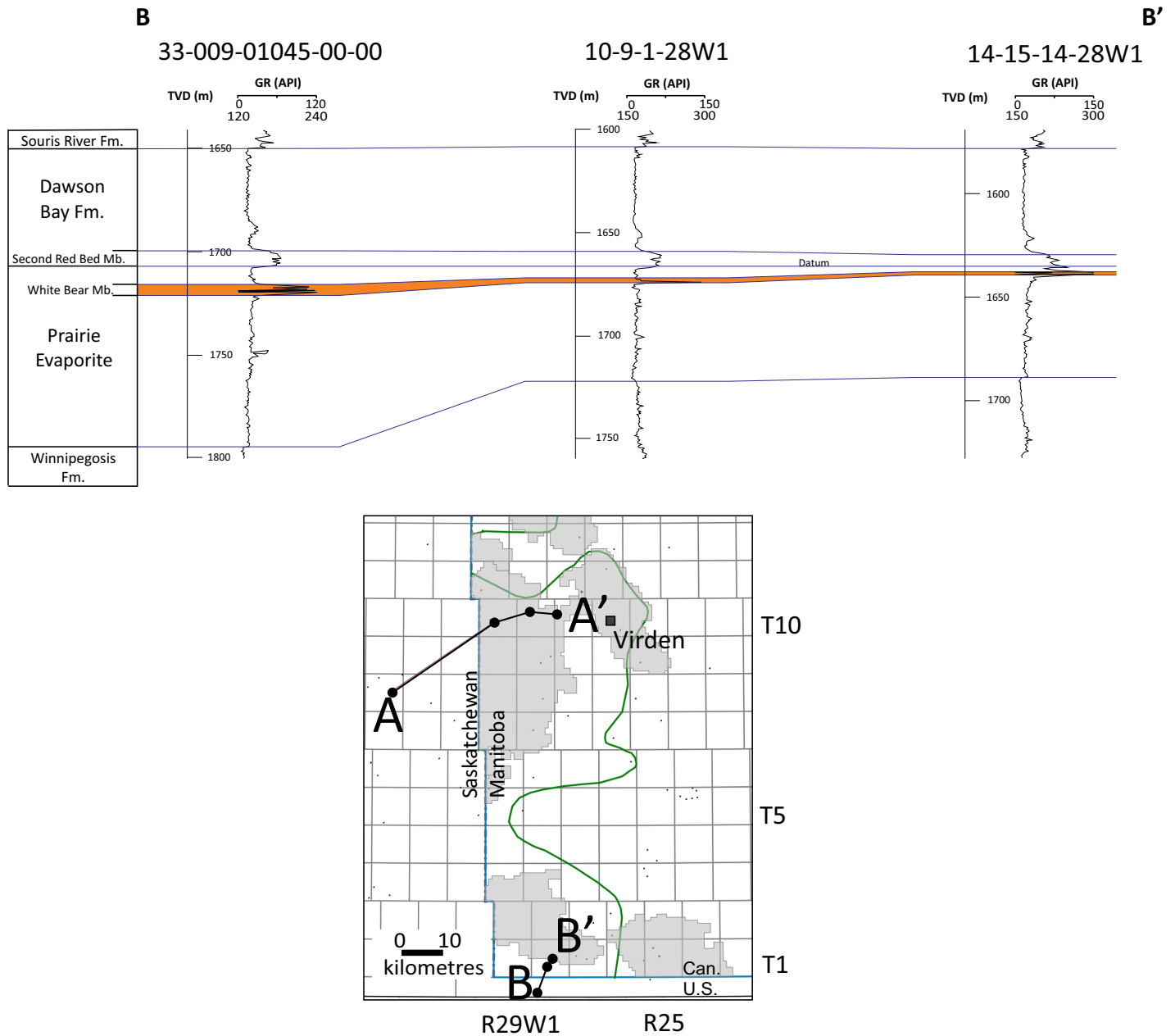
### **Northern extension of potash area**

The potash distribution north of Twp. 19 and east of Rge. 29W1 represents a new interpretation of the potash extent in Manitoba (Figure GS2022-10-2). Well control is scarce in this area, however, three components suggested that the potash extended farther north and east. These components are 1) the isopach contours of the Prairie Evaporite salt (Bezys and Conley, 1998), 2) the log signatures and presence of clay beds in the control wells in Rge. 27W1, and 3) the zero edge of the Esterhazy Member from Yang et al. (2018). This revised potash zero edge in the area between Twp. 19 and 25 follows approximately the 90 m Prairie Evaporite salt isopach contour of Bezys and Conley (1998). In other areas, 90 m is the approximate salt thickness needed for any potash beds to be deposited and/or preserved in Manitoba. It is possible the potash extends farther north into Twp. 25–28, but the zero edge in Saskatchewan, as it is drawn at the time of writing (Yang et al., 2018), is the determining factor to stop the northern extension at Twp. 25. The revision of the potash edge in this area resulted in approximately 840 km<sup>2</sup> (approximately nine townships in area) of new potash exploration area in Manitoba, although only new exploration test wells can verify the actual presence of potash in these areas.

### **Total salt zero edge**

The zero edge of total salt distribution outlines the eastern extent of the thick package of evaporitic minerals consisting of halite, sylvite and carnallite within the Prairie Evaporite. This edge was also updated in this report (Figure GS2022-10-2), specifically in the area in the southeastern end of the Manson Field in Twp. 12–13, Rge. 27W1 and along the eastern edge of the Virden Field in Twp. 10–11, Rge. 25–26W1.

In the Manson Field, stratigraphic information gathered through recent oil pool development uncovered a complex series of multistage structural disturbances related to salt dissolution and collapse. The oil pool development method (vertical and direction wells dominating), oil pool distribution (small isolated pools) and producing intervals that span multiple horizons in the southeastern end of this oil field are strikingly different from those in the northwestern part of the Manson Field and even to the south in the Virden Field. The latter are dominated by horizontal well developments in large expansive oil pools with production from a focused stratigraphic interval. These factors together inform the more precise location of the salt edge in this area. Additionally, core from the southeastern area shows large open fractures, slickensides indicative of faulting and brecciation in the overlying interval from the Mississippian Lodgepole For-



**Figure GS2022-10-6:** South to north cross-section B–B’ from North Dakota (well 33-009-01045-00-00) to Pierson potash area, southwestern Manitoba. Datum is top of Prairie Evaporite. Inset map shows the location of the cross-section and the eastern edge of salt distribution (green line). Abbreviations: 10-9-1-28W1, well at L.S. 10, Sec. 9, Twp. 1, Rge. 28, W 1<sup>st</sup> Mer.; Fm., Formation; GR, gamma ray; Mb., Member; TVD, true vertical depth.

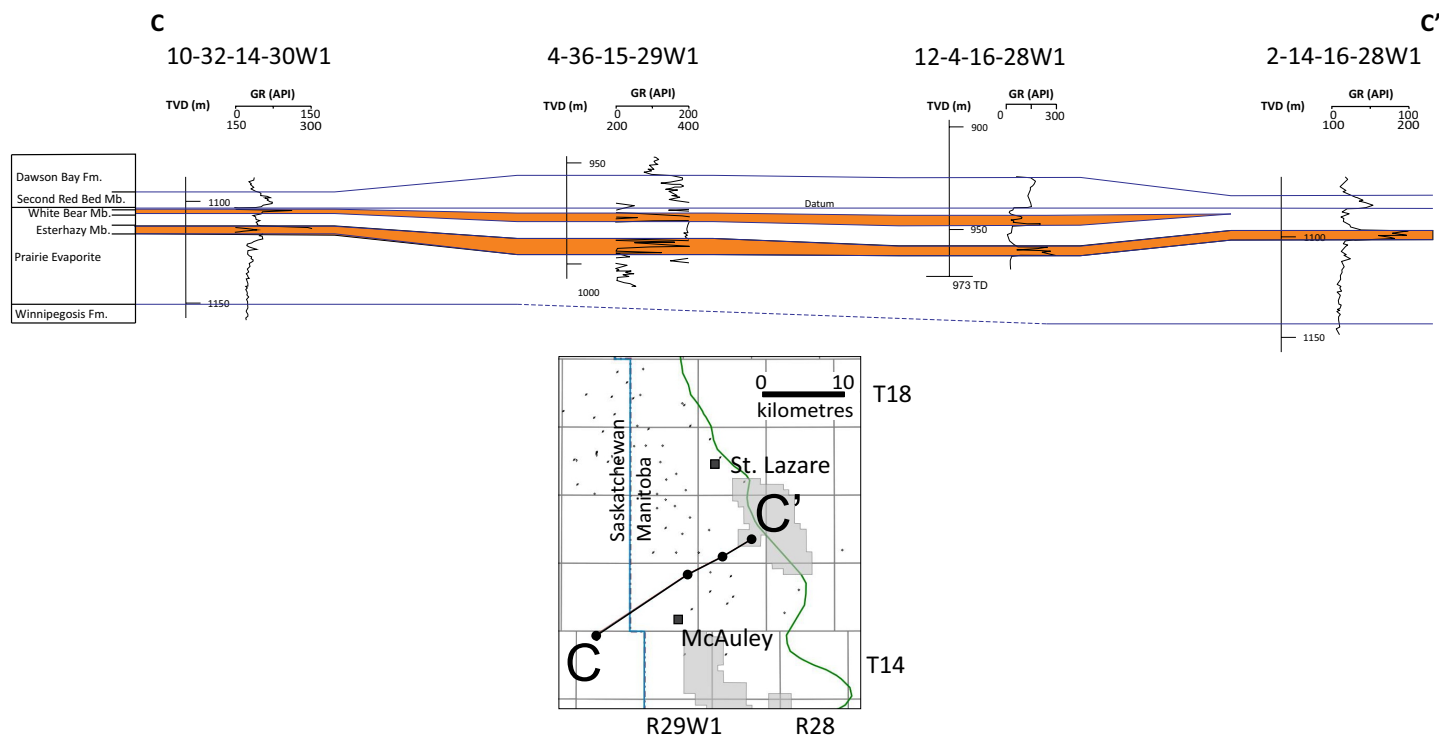
mation to the Jurassic Melita Formation resulting from the complete dissolution of the salt below.

In the Virden Field, the salt zero edge was moved to match more closely the edge of the oil pools; this was done based on the location of dry wells, oil pool boundaries and the structural mapping of the Lodgepole Formation (Klassen, 1996; Nicolas, 1999). The deposition of the Lodgepole Formation and development of this oil field is known to have been strongly controlled by structural disturbances in the Birdtail-Waskada Zone—a known structural feature, which postdated Prairie Evaporite deposition (Klassen, 1996), directly affected by the partial to complete dissolution of the salt beds.

### Economic considerations

Potash deposits are mined for use dominantly by the fertilizer industry to increase crop yields. With growing global demand for potash, identifying new deposits helps to add reserves, which will ensure security of product for generations to come. The development of the first potash mine in Manitoba is attracting global interest to the province. Through renewed research and mapping of the potash layers across the basin, and better geoscientific understanding of the distribution of the potash members in Manitoba, the area of potential potash occurrences has been expanded and fine-tuned, resulting in approximately 840 km<sup>2</sup> of new potash exploration area.





**Figure GS2022-10-7:** Southwest to northeast cross-section C–C' from Saskatchewan to the southern extent of the McAuley-Russell potash area in southwestern Manitoba. Datum is top of Prairie Evaporite. Inset map shows the location of the cross-section and the eastern edge of salt distribution (green line). Abbreviations: 10-32-14-30W1, well at L.S. 10, Sec. 32, Twp. 14, Rge. 30, W 1<sup>st</sup> Mer.; Fm., Formation; GR, gamma ray; Mb., Member; TD, total depth; TVD, true vertical depth.

## Acknowledgments

The authors would like to thank T. Hodder and T. Kennedy for their technical and critical review of this report.

## References

- Bannatyne, B.B. 1960: Potash deposits, rock salt, and brines in Manitoba; Manitoba Department of Mines and Natural Resources, Mines Branch, Publication 59-1, 30 p., URL <<https://manitoba.ca/iem/info/libmin/PUB59-1.pdf>> [October 2022].
- Bannatyne, B.B. 1983: Devonian potash deposits of Manitoba (parts of 62F/3, 6, 11 and 14); Manitoba Department of Energy and Mines, Mineral Resources Division, Open File Report OF83-3, 27 p., URL <<https://manitoba.ca/iem/info/libmin/OF83-3.pdf>> [October 2022].
- Bezys, R.K. and Conley, G.G. 1998: Manitoba stratigraphic database and the Manitoba stratigraphic map series; Manitoba Energy and Mines, Geological Services, Open File Report OF98-7, CD-ROM.
- Klassen, H.J. 1996: An overview of the regional geology and petroleum potential, Lodgepole Formation, southwestern Manitoba; Manitoba Energy and Mines, Petroleum and Energy Branch, Petroleum Open File Report POF 15-96, 42 p., URL <[https://manitoba.ca/iem/petroleum/pubcat/pof\\_15-96.zip](https://manitoba.ca/iem/petroleum/pubcat/pof_15-96.zip)> [October 2022].
- Kruger, N. 2014: The potash members of the Prairie Formation in North Dakota; North Dakota Geological Survey, Report of Investigations No. 113, 43 p.
- Nicolas, M.P.B. 1999: Structure contour map of the Mississippian Upper Virden Member, Lodgepole Formation, Virden Field area; Manitoba Conservation, Petroleum and Energy, Stratigraphic Map Series M-4, scale 1:250 000, URL <[https://manitoba.ca/iem/petroleum/pubcat/new/m\\_4.tif](https://manitoba.ca/iem/petroleum/pubcat/new/m_4.tif)> [October 2022].
- Nicolas, M.P.B. 2015: Potash deposits in the Devonian Prairie Evaporite, southwestern Manitoba; in Report of Activities 2015, Manitoba Mineral Resources, Manitoba Geological Survey, p. 97–105, URL <<https://manitoba.ca/iem/geo/field/roa15pdfs/GS-8.pdf>> [October 2022].
- Nicolas, M.P.B. 2019: Beyond oil: mineral potential within and below Manitoba's oil fields; Central Canada Mineral Exploration Convention, November 18–19, 2019, Winnipeg, Manitoba, Geoscientific Presentation PRES2019-6, poster, URL <<https://manitoba.ca/iem/geo/techposters/2019/PRES2019-6.pdf>> [October 2022].
- Yang, C. and Love, M. 2015: Potash-rich members of the Devonian Prairie Evaporite in Saskatchewan: isopachs, carnallite contours and K<sub>2</sub>O grade; Saskatchewan Ministry of Economy, Saskatchewan Geological Survey, Open File 2015-2, 3 maps.
- Yang, C., Jensen, G. and Berenyi, J. 2009: The stratigraphic framework of the potash-rich members of the Middle Devonian Upper Prairie Evaporite Formation, Saskatchewan; in Summary of Investigations 2009, Volume 1, Saskatchewan Geological Survey, Saskatchewan Energy and Resources, Miscellaneous Report 2009-4.1, Paper A-4, p. 1–28.
- Yang, C., Schuurmans, E. and Love, M. 2018: Updated isopach maps of the potash-rich members of the Devonian Prairie Evaporite in Saskatchewan; Saskatchewan Ministry of Energy and Resources, Saskatchewan Geological Survey, Open File 2018-1, 6 maps.