GS2025-12

Geochemistry of the Carman Sand and lower unit sand of the Winnipeg Formation, southern Manitoba (parts of NTS 62H, P)

by V.L. Markstrom

Summary

Silica sand derived from two layers of the Winnipeg Formation, the lower unit sand and the Carman Sand, have significant potential for economic development due to their high silica content. As part of an ongoing project on the Winnipeg Formation, the Manitoba Geological Survey (MGS) has reconstructed the Carman Sand isopach and structure maps to better reflect geological boundaries. New isopach and structure maps were constructed for the basal sandstone, a blanket-type sandstone that forms the base of the lower unit. These maps were used to assess the distribution differences between the lowermost sandstone layer and the interbedded shale and sand that make up the rest of the lower unit. The isopach map illustrates that the thickest part of the basal sandstone occurs near the Dauphin area of the province and is thinnest north of the City of Winnipeg. Geochemical analysis of 20 Winnipeg Formation samples was completed to evaluate the difference between the two sand layers with the highest economic potential: the Carman Sand and lower unit sand. Concentrations of SiO_2 from the Carman Sand samples ranged from 95.74 to 99.68%, with only minor spatial and stratigraphic variations. The lower unit sand had a larger SiO_2 concentration range of 65.55–98.22%, consistent with previous research.

In Brief:

- Mapping of the basal sandstone of the Winnipeg Formation in southern Manitoba shows variability in distribution of sand
- Results from geochemical analysis illustrates the difference between the two most economically viable sand layers in the Winnipeg Formation

Citation:
Markstrom, V.L. 2025: Geochemistry of the Carman Sand and lower unit sand of the Winnipeg Formation, southern Manitoba (parts of NTS 62H, P); *in* Report of Activities 2025, Manitoba Business, Mining, Trade and Job Creation, Manitoba Geological Survey, p. 120–127.

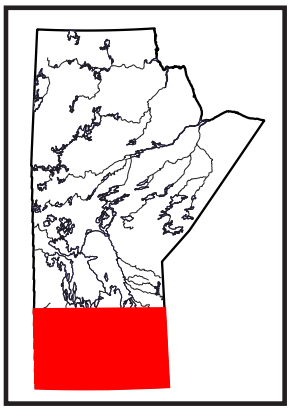
Introduction

The Winnipeg Formation is composed mostly of interlayered quartz-rich sandstones and arenaceous shales (McCabe, 1978). McCabe (1978) and Markstrom (2024) include detailed information on the geology of the Winnipeg Formation. There are multiple sand-bearing layers within the Winnipeg Formation (McCabe, 1978), with previous research identifying the lower unit sand and Carman Sand as those of highest economic potential (Figure GS2025-12-1). The sand from the lower unit has been characterized through sieve and geochemical analyses (Watson, 1985; Gale et al., 1993; Lapenskie, 2016) and is primarily used to produce glass (Watson, 1985). The Carman Sand has yet to be extracted for industrial use due to difficulties extracting the unconsolidated sand (Watson, 1985) from the subsurface. However, renewed interest in the economic potential of the Carman Sand has led to recent exploration and geological investigations in south-central Manitoba (Markstrom, 2024).

Quantifying the differences between the lower unit sand and the Carman Sand will provide a better understanding of the depositional setting of the Winnipeg Formation. This will help with exploration of these deposits and potentially locate other areas of high economic potential for silica sand. This project will also contribute toward formalizing the stratigraphic nomenclature in Manitoba, and a better understanding of the stratigraphic positioning of these sand layers. Additionally, geochemical characterization of the sand beds will inform exploration decisions and the economic development of both sand beds.

This study is a continuation of the Winnipeg Formation project introduced in Markstrom (2024). The goals for this year were to

1) update and construct new isopach and structure maps based on data collected from Markstrom (2024);
2) conduct whole-rock geochemical analysis on the Carman Sand and lower unit sand;
3) assess the stratigraphic and spatial variability within the Carman Sand; and
4) compare results from Carman Sand samples with lower unit sand samples to illustrate differences between the layers.



Methodology

Isopach and structure maps of the Carman Sand were updated (Markstrom, 2024) and new maps were constructed for the basal sandstone. These maps were made using drillcore data from the Williston Basin Targeted Geoscience Initiative (TGI) database (TGI Williston Basin Working Group, 2008b)

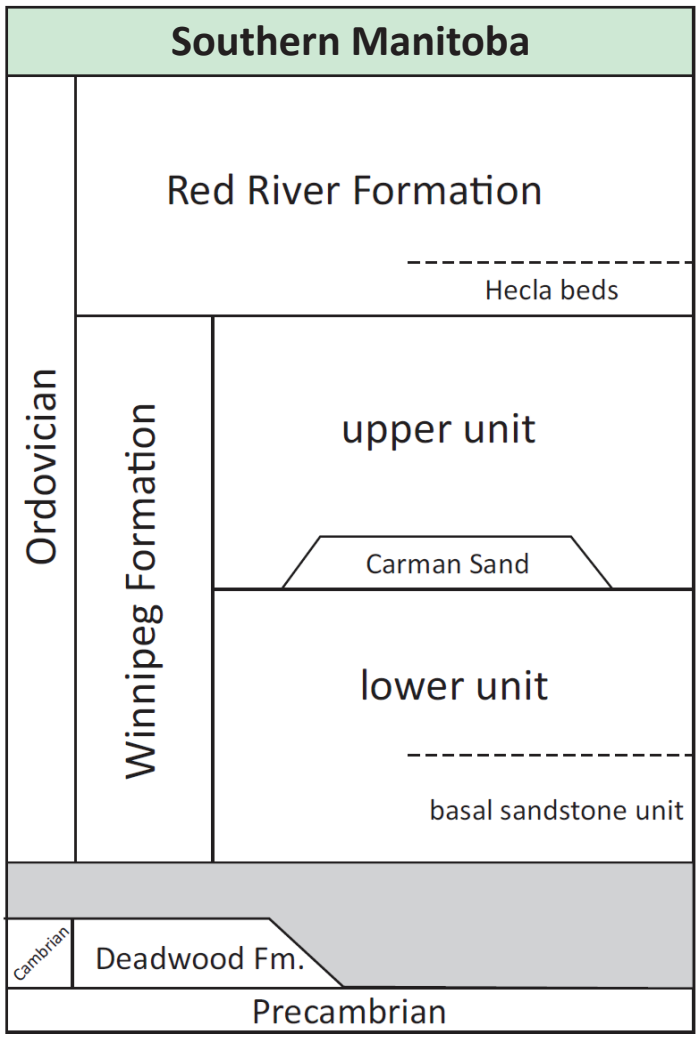


Figure GS2025-12-1: *Stratigraphic column of the lower Paleozoic of southern Manitoba in the Williston Basin (Markstrom, 2024).*

and the Manitoba Stratigraphic Database (MSD; Bezys and Conley, 1999) as well as borehole data from the Integrated Mining and Quarrying System (iMaQs; Manitoba Business, Mining, Trade and Job Creation, 2025). The Natural Neighbours geoprocessing tool was used in Esri® ArcGIS® Pro to generate these maps, which were cropped to the Phanerozoic edge of the Williston Basin.

A total of 20 samples were collected from drillcore and outcrop for geochemical analysis, sample information can be found in Table 1_2 of Data Repository Item DRI2025028 (Markstrom, 2025[1]). Thirteen Carman Sand samples from four drillcore in south-central Manitoba were provided by SiO Silica, Inc. for analysis (Figure GS2025-12-2a). Two lower unit samples were cut and collected from drillcore 11-29-1-25 (oil and gas well licence 2543, Manitoba Business, Mining, Trade and Job Creation, Winnipeg) at the MGS Midland Sample and Core Library (core library) in Winnipeg, Manitoba (Figure GS2025-12-2b). Five samples were collected from the lower unit sand from one outcrop near Seymourville, Manitoba (Figure GS2025-12-2c, d) with site access provided by Canadian Premium Sand Inc. Only one site was sampled because the geochemical composition of the lower unit has been documented previously by several authors (Watson, 1985; Gale et al., 1993; Lapenskie, 2016). At the core library, a fraction of all samples were oven dried, crushed in a steel jaw crusher and pulverizer and milled to <200 mesh for geochemical analysis. Whole-rock total digestion (lithium metaborate/tetraborate fusion) followed by inductively coupled plasma–optical emission spectroscopy (ICP-OES) and inductively coupled plasma–mass spectrometry (ICP-MS) was conducted on all samples by Activation Laboratories Ltd. (Ancaster, Ontario). The OREAS® 21f (quartz sand) certified reference material was also submitted for analysis to validate the quality of the geochemical data. Sieve analysis was also conducted on four samples by the Central Lab of the Materials Engineering Branch, Manitoba Infrastructure (Winnipeg, Manitoba). The results can be found in Table 2_1 to 2_5 of Markstrom (2025), however, due to the small sample size the results will not be discussed in this report.

Results

Isopach maps

The updated Carman Sand isopach map (Figure GS2025-12-3) shows a modified bed boundary that better reflects interpreted geological boundaries as compared with Markstrom (2024). Additionally, an isopach map of the lower unit basal sandstone was constructed (Figure GS2025-12-4). This isopach map illustrates that the basal sandstone is thickest near Dauphin Lake and east of Lake Manitoba and thins toward the northern and southeastern edges of the Winnipeg Formation (Figure GS2025-12-4). The southern extent of the lower unit basal sandstone overlaps with parts of the overlying Carman Sand in places (Markstrom, 2024). The thinnest part of the basal sandstone is located just north of the City of Winnipeg. Structure maps for the Carman Sand and basal sandstone are consistent with previous research and did not significantly differ from the TGI maps (TGI Williston Basin Working Group, 2008a).

Geochemistry

The total digestion (lithium metaborate/tetraborate fusion) geochemical analysis of Carman Sand (n = 13) indicates that the sand is composed of 95.74–99.68 wt. % SiO_2. There are minor variations in SiO_2 concentrations between samples from drillcore Den 269-1 but no obvious correlation with depth. The SiO_2 values from drillcore Den 245-1 have a greater variability in SiO_2 concentration compared to drillcore Den 269-1, but no obvious correlation with depth either. The chemical impurities within the Carman

[1] MGS Data Repository Item DRI2025028, containing the data or other information sources used to compile this report, is available online to download free of charge at https://manitoba.ca/iem/info/library/downloads/index.html, or on request from minesinfo@gov.mb.ca, or by contacting the Resource Centre, Manitoba Business, Mining, Trade and Job Creation, 360-1395 Ellice Avenue, Winnipeg, Manitoba R3G 3P2, Canada.

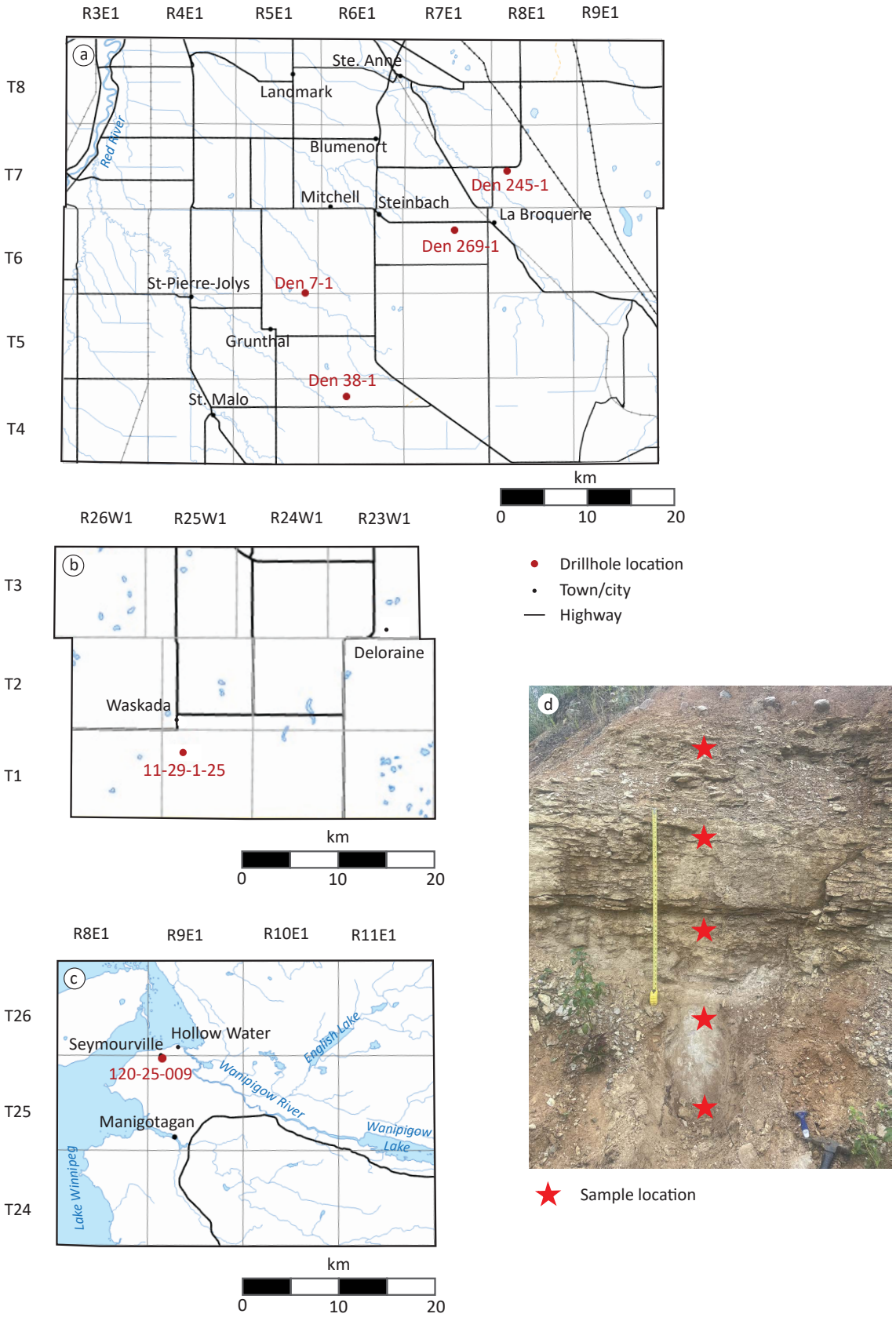


Figure GS2025-12-2: *Location of drillhole and outcrop sample locations in southern Manitoba:* ***a)*** *drillhole locations for the Carman Sand samples;* ***b)*** *location of drillhole 11-29-1-25;* ***c)*** *site 120-25-009 – Seymourville;* ***d)*** *stratigraphic position of Winnipeg Formation lower unit sand samples that were collected at site 120-25-009. Measuring tape shows 1 m.*

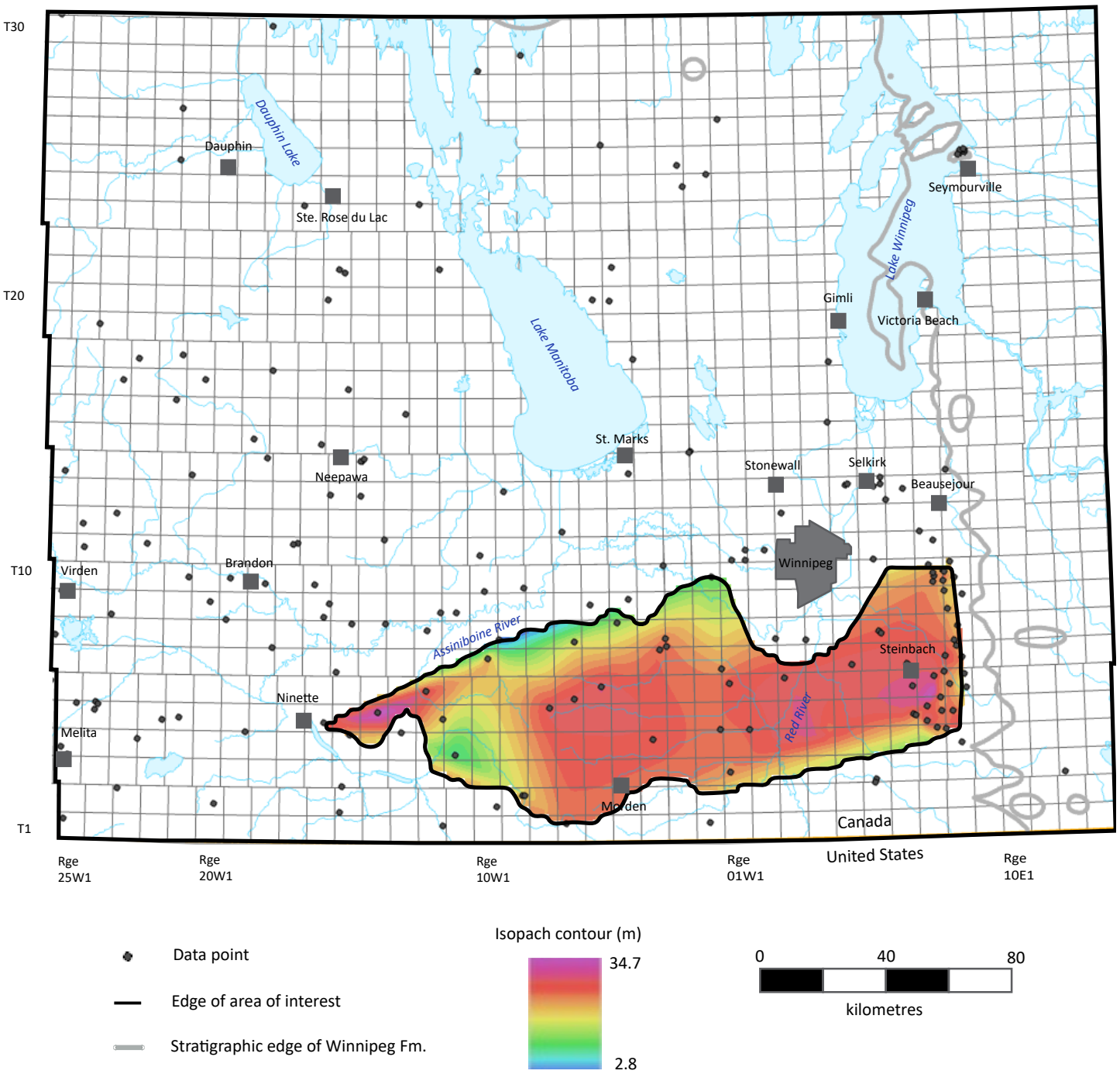


Figure GS2025-12-3: *Isopach map of the Carman Sand of the Winnipeg Formation in southern Manitoba. This preliminary map was constructed using a computer-generated model constrained to the project dataset. Data points from TGI Williston Basin Working Group (2008b). Basemap was created using ArcGIS® software by Esri. ArcGIS® is the intellectual property of Esri and is used herein under license. Copyright © Esri. All rights reserved. For more information about Esri software, please visit <https://esri.ca/>.*

Sand are primarily Al_2O_3, Fe_2O_3, MgO, CaO and TiO_2. Most of the Carman Sand samples have concentrations of total impurities between 0.83 to 1.92 wt. %. However, sample 120-25-Den245_1-174 has a higher concentration of total impurities, 3.32 wt. %, and has the lowest SiO_2 concentration (95.74 wt. % SiO_2) of the Carman Sand samples.

The lower unit sand samples from the Seymourville site and drillcore 11-29-1-25 (n = 7) have a greater range in SiO_2 concentrations, 65.55–98.22 wt. %, compared to the Carman Sand samples. The lower unit sand samples collected from the Seymourville site have no apparent correlation between SiO_2 concentration and the stratigraphic position of the sample. The impurities in the

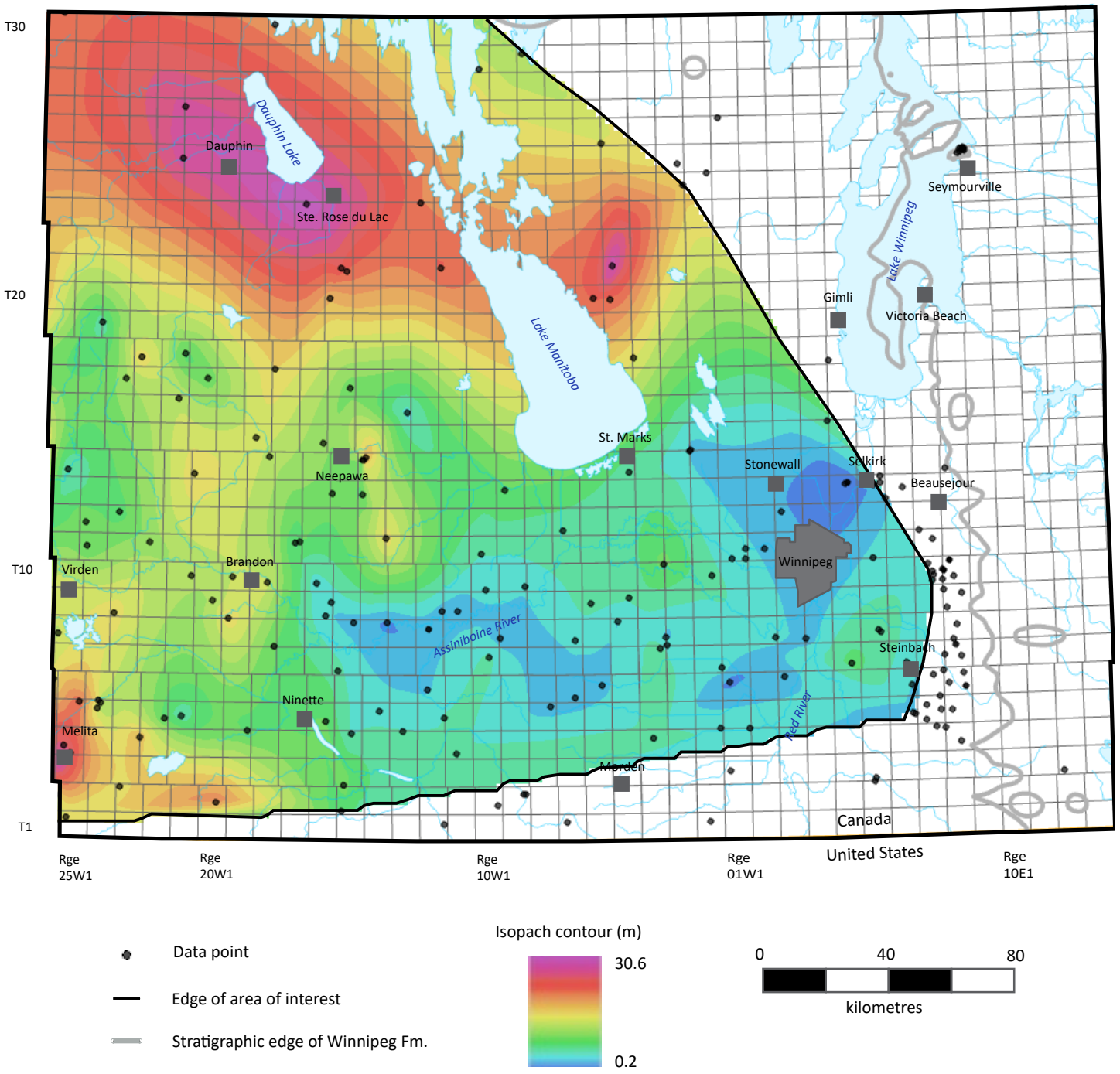


Figure GS2025-12-4: *Isopach map of the basal sandstone of the Winnipeg Formation in southern Manitoba. This preliminary map was constructed using a computer-generated model constrained to the project dataset. Data points from TGI Williston Basin Working Group (2008b). Basemap was created using ArcGIS® software by Esri. ArcGIS® is the intellectual property of Esri and is used herein under license. Copyright © Esri. All rights reserved. For more information about Esri software, please visit <https://esri.ca/>.*

lower unit sand samples are primarily Al_2O_3, Fe_2O_3, MgO, CaO, TiO_2 and K_2O and the samples have a greater range in total impurities (between 1.44 and 23.52 wt. %) compared to the Carman Sand samples (0.83–3.32 wt. %). The observed trends in chemical composition of the lower unit sand are consistent with previous research (Watson, 1985; Gale et al., 1993; Lapenskie, 2016).

Discussion

Isopach maps

The basal sandstone isopach map (Figure GS2025-12-4) was compared against the entire lower unit isopach map constructed by Markstrom (2024) to identify any differences in distribution

between the lowermost sandstone and the interbedded sand and shale that make up the rest of the lower unit. Since the basal sandstone has been correlated with the lower part of the Black Island Member in Saskatchewan (McCabe, 1978), identifying its distribution in Manitoba may prove useful for future stratigraphic work and help formalize the nomenclature of the Winnipeg Formation.

The limited data suggests the basal sandstone is thickest near Dauphin Lake and east of Lake Manitoba (Figure GS2025-12-4). When compared to the isopach map of the entire lower unit (Figure GS2025-12-5), it is apparent that the Dauphin Lake area is composed primarily of the basal sandstone with little of the lower unit interbedded sand and shale. A similar pattern is seen in the Melita area where most of the lower unit is com-

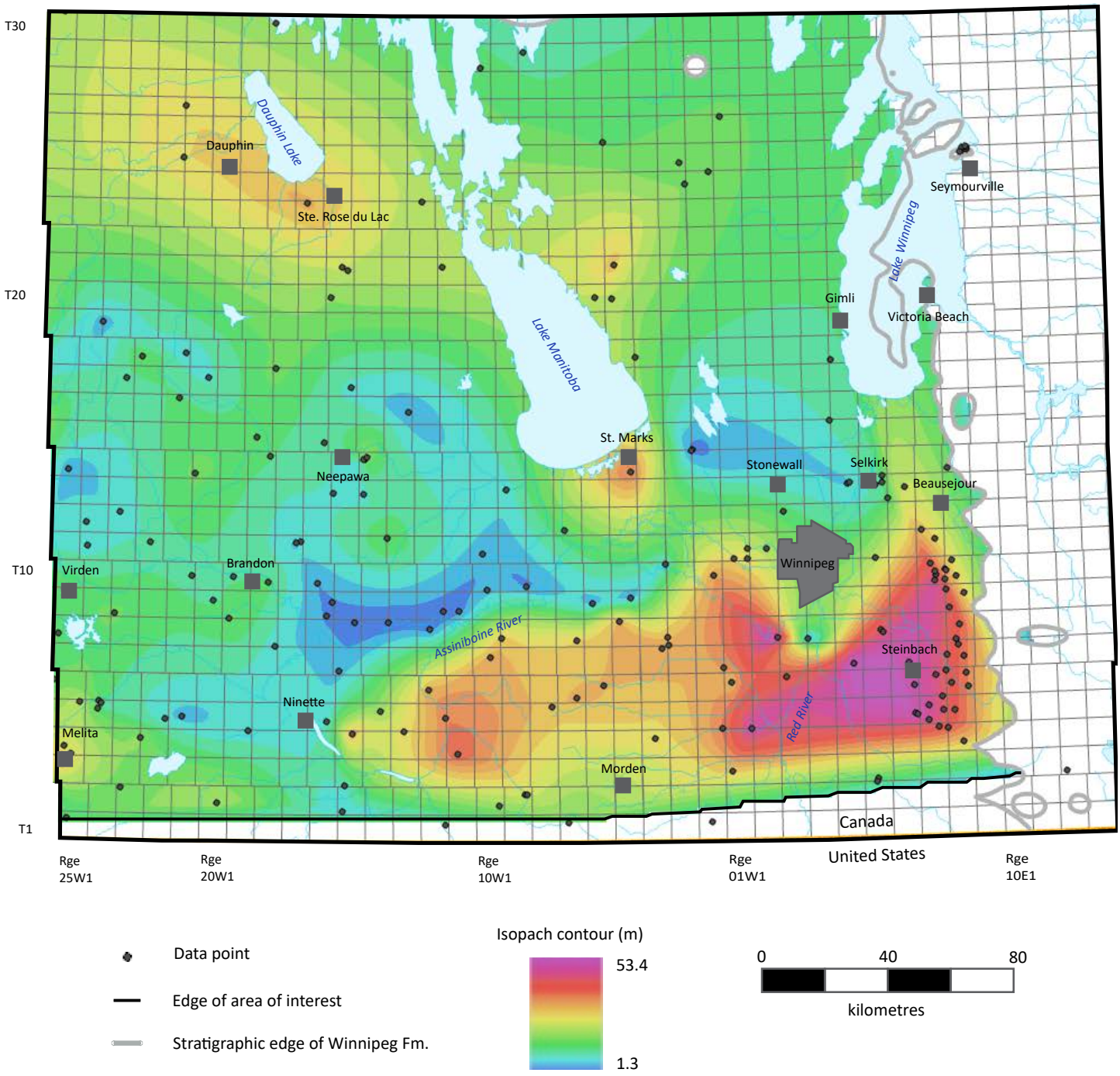


Figure GS2025-12-5: *Isopach map of the lower unit of the Winnipeg Formation in southern Manitoba (Markstrom, 2024). This preliminary map was constructed using a computer-generated model constrained to the project dataset. Data points from TGI Williston Basin Working Group (2008b). Basemap was created using ArcGIS® software by Esri. ArcGIS® is the intellectual property of Esri and is used herein under license. Copyright © Esri. All rights reserved. For more information about Esri software, please visit <https://esri.ca/>.*

posed of a thick section of basal sandstone, and the rest of the lower unit is almost absent. The opposite trend can be observed in the south-central portion of the province. The basal sandstone appears thinnest in an area roughly between Brandon and Selkirk; therefore, most of the lower unit present in this area is likely composed of the lower unit layers of sand and shale. It is important to note that parts of the overlying Carman Sand spatially overlap in this area.

Geochemistry

The SiO_2 concentrations of the seven Carman Sand samples from drillhole Den 269-1 have little variation regardless of their drillcore depth. This implies that stratigraphically the geochemical composition is consistent throughout the Carman Sand at this location. In samples from a location nearby, drillhole Den 245-1, there is some variability depending on depth interval. The lowest SiO_2 concentration in the Carman Sand, 95.74 wt. % in drillcore Den 245-1, was measured at the top of the drillcore but samples below have concentrations around 97–98 wt. % SiO_2. Only one sample was collected from each of the Den 7-1 and Den 38-1 drillcore, therefore, the stratigraphic variability at these locations cannot be verified.

The results from this analysis show there is minor spatial variability in SiO_2 concentrations of the Carman Sand when comparing the average results from drillcore Den 269-1 (average 98.55 wt. % SiO_2), Den 245-1 (average 97.52 wt. % SiO_2), Den 38-1 (99.68 wt. % SiO_2) and Den 7-1 (97.41 wt. % SiO_2). Due to the low sample population and limited sampling sites in this study, it is difficult to constrain the stratigraphic and spatial variability of SiO_2 that may be occurring in the Carman Sand. In order to address this shortfall, additional data from more localities of the Carman Sand are needed. In contrast, the lower unit sand has a much larger variability in SiO_2 concentrations. Although the average SiO_2 concentration for the lower unit sand (87.66 wt. % SiO_2) is lower than the Carman Sand average (98.23 wt. % SiO_2), samples 120-25-009-01 and 120-25-11_29_1_25-1924.45 have concentrations within the range observed for the Carman Sand. At the Seymourville site, the SiO_2 concentrations vary significantly, which is consistent with previous research (Watson, 1985). However, no trend between SiO_2 concentration and stratigraphic position of the samples is apparent.

Future work

Future research on the Winnipeg Formation will include additional geochemical analyses of the Carman Sand. Samples within a larger spatial and stratigraphic context will better confirm and constrain any changes within the units. Sieve analysis will also be conducted on additional lower unit sand and Carman Sand samples to characterize grain distributions and further assess differences between the two sand layers. Passive seismic studies will be conducted to better understand the geometry of the Winnipeg Formation and the topography of the Precambrian basement. This information is important because the Precambrian topography could have had a direct impact on the thickness and spatial distribution of different units within the Winnipeg Formation.

Economic considerations

There are many industrial uses for silica sand but its industrial application is greatly affected by composition and grain-size characteristics. The 20 samples tested in this study do not meet the specifications for high-quality glass production (Vatalis et al., 2015). However, it is important to note that the none of the samples were cleaned or refined before analysis and it is difficult to confirm industrial usage for each sand layer. Higher SiO_2 concentrations might be achievable for the Carman Sand and lower unit sand depending on the cleaning methods used.

Acknowledgments

The author would like to thank Sio Silica, Inc. and Canadian Premium Sand Inc. for site and sample access. Logistical and field support from C. Epp, E. Ralph and P. Belanger (Manitoba Geological Survey) is appreciated. Reviews of this report were provided by T.J. Hodder and M.S. Gauthier (Manitoba Geological Survey).

References

Bezys, R.K. and Conley, G.G. 1999: Manitoba Stratigraphic Database and the Manitoba Stratigraphic Map Series; Manitoba Energy and Mines, Geological Services, Open File Report OF98-7, 1 CD-ROM.

Gale, G.H., Halden, N.M. and Mejia, S. 1993: High purity silica studies-geochemical and mineralogical studies of Winnipeg Formation silica sands; *in* Report of Activities 1993, Manitoba Energy and Mines, Geological Services, p. 146–148.

Lapenskie, K. 2016: Preliminary investigations into the high-purity silica sand of the Winnipeg Formation, southern Manitoba; *in* Report of Activities 2016, Manitoba Growth, Enterprise and Trade, Manitoba Geological Survey, p. 176–180.

Manitoba Business, Mining, Trade and Job Creation 2025: iMaQs, Manitoba's Integrated Mining and Quarrying System; Manitoba Business, Mining, Trade and Job Creation, URL <https://manitoba.ca/iem/mines/imaqs/index.html> [January 2025].

Markstrom, V.L. 2024: Distribution of the lithological units of the Winnipeg Formation, southern Manitoba (NTS 62F–K, N–P); *in* Report of Activities 2024, Manitoba Economic Development, Investment, Trade and Natural Resources, Manitoba Geological Survey, p. 185–191.

Markstrom, V.L. 2025: Sieve and geochemical analyses data from samples of the Winnipeg Formation in southern Manitoba (parts of NTS 62H, P); Manitoba Business, Mining, Trade and Job Creation, Manitoba Geological Survey, Data Repository Item DRI2025028, Microsoft® Excel®.

McCabe, H.R. 1978: Reservoir potential of the Deadwood and Winnipeg formations, southwestern Manitoba; Manitoba Department of Mines, Resources and Environmental Management, Mineral Resources Division, Geological Paper GP78-3, 54 p.

TGI Williston Basin Working Group 2008a: Ordovician Winnipeg Formation: structure contour; Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, Stratigraphic Map SM2008-OW-I, scale 1:1 000 000, URL <https://www.gov.mb.ca/iem/geo/willistontgi/mapfiles/pdfs/055_ord_winnipeg_fm_str.pdf> [September 2025].

TGI Williston Basin Working Group 2008b: TGI II Williston Basin database service, lower Paleozoic data; Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, URL <https://www.manitoba.ca/iem/geo/willistontgi/database.html> [September 2025].

Vatalis, K.I., Charalambides, G. and Benetis, N.P. 2015: Market of high purity quartz innovative applications; Procedia Economics and Finance, v. 24, p. 734–742.

Watson, D.M. 1985: Silica in Manitoba; Manitoba Energy and Mines, Geological Services, Economic Geology Report ER84-2, 35 p.