GS2024-22

Distribution of the lithological units of the Winnipeg Formation, southern Manitoba (NTS 62F–K, N–P)

by V.L. Markstrom

Summary

Silica sand is a mineral with many industrial uses, including the production of silicon metal, which is on Canada's critical minerals list. In Manitoba, the purest and highest quality sand for economic development is derived from the Ordovician Winnipeg Formation. Due to increased interest in Manitoba's silica sand, the formation is being re-examined by the Manitoba Geological Survey. Within the Winnipeg Formation, the Carman Sand is of particular interest due to its high purity and quality, making it an excellent source of proppant sand. Isopach and structure maps were created for the Winnipeg Formation, including for the upper unit, the Carman Sand and the lower unit. The Winnipeg Formation is thickest in southern Manitoba, measuring 75 m, and gradually thins northward, with a sharp decrease in thickness toward the eastern edge of the Williston Basin, to <1 m. This pattern is observed in both the upper and lower units, although each unit shows spatial variability in thickness. The upper unit is thickest in the southwest measuring 75 m, whereas the lower unit is the thickest in south-central Manitoba measuring 53.4 m. The Carman Sand is restricted to a small area in the south. Most of the Carman Sand exceeds 20 m in thickness, with certain areas of the lens reaching up to 34.7 m near the City of Steinbach. Based on the structural maps, the Winnipeg Formation and all its lithological units dip toward the southwestern corner of the province. To the northeast, the Winnipeg Formation ascends to the surface along the boundary of the Williston Basin where it outcrops periodically. These trends allow to better constrain the thickness and distribution of the Winnipeg Formation, which is essential for future economic development.

In Brief:

- Mapping of the lithological units of the Winnipeg Formation in southern Manitoba shows variability in distribution of sand
- Map of the Carman sand outlines area for high-quality silica sand exploration

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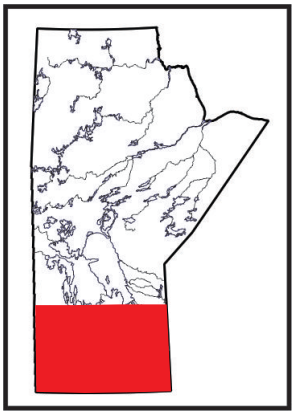
Introduction

Due its high quality, the silica sand derived from the Ordovician Winnipeg Formation can be used for a variety of industrial applications, including solar panels and proppant sand. Both the upper and lower units contain silica sand, but only the lower unit has been quarried in Manitoba to date. The extracted sand was primarily used to produce glass (Watson, 1985). Renewed interest in the high-quality silica sand of the Winnipeg Formation has resulted in exploration near the community of Seymourville and east of the City of Steinbach. Within the upper unit of the Winnipeg Formation, there is a decametres-thick horizon of unconsolidated silica sand, the Carman Sand (Figure GS2024-22-1), which has recently gained more attention as a potential source for proppant sand due to its optimal grain size, well-sorted nature, and sphericity and strength of the grains. Though the Winnipeg Formation has been studied in the past, renewed exploration has provided data from new drillholes and samples to study this unique formation.

The objectives of this study are to

1) map and re-evaluate the distribution of the Ordovician Winnipeg Formation and its lithological units across southern Manitoba;
2) highlight the difference between the spatial distribution of the upper and lower units;
3) map the basal sandstone bed of the lower unit and re-examine its economic potential; and
4) constrain the extent of the Carman Sand to help support future economic development.

Presented in this report are the preliminary isopach maps of the Winnipeg Formation, providing a visual presentation of its distribution and the difference between the spatial distribution of the lithological units.



Previous work

A report on the Ordovician stratigraphy of the Lake Winnipeg area was published by Baillie (1952), and included descriptions of outcrops of the Winnipeg Formation in the Hecla, Black Island and Punk Island area. In this report, Baillie (1952) informally divided the Winnipeg Formation into upper and lower units. The first comprehensive subsurface study was published by Andrichuk (1959),

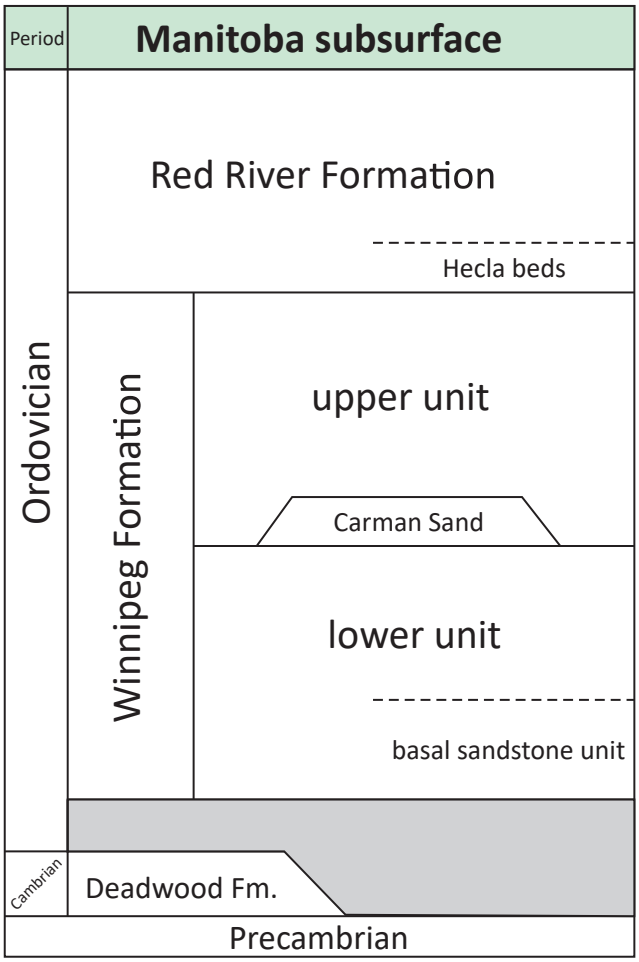


Figure GS2024-22-1: *Stratigraphic column of the lower Paleozoic in the subsurface of southern Manitoba.*

who constructed isopach and lithofacies maps for both units and identified the Carman Sand lens. Vigrass (1971) further studied the lithofacies of the Winnipeg Formation in Manitoba and Saskatchewan, providing detailed lithological descriptions and depositional environments for each unit. McCabe (1978) published a thorough investigation into the oil reservoir potential of the Cambrian Deadwood Formation and Ordovician Winnipeg Formation for southwestern Manitoba. This study included an extensive series of isopach and structure maps as well as a summary of the Cambrian–Ordovician paleogeography. The economic potential of silica sand was described by Watson (1985) who summarized the history, lithology and lithogeochemistry of various silica sand sources in Manitoba, including the lower unit of the Winnipeg Formation. Gale et al. (1993) examined the lithogeochemistry of lower unit samples taken from Black Island, recording the distribution of impurities after industrial processing. The most recent publication (Lapenskie, 2016) included an investigation of two Winnipeg Formation outcrops along the northern edge of the Williston Basin and an assessment of the lithogeochemistry of samples of the lower unit from three sites across Manitoba.

Regional geology and stratigraphy

The Winnipeg Formation is composed of interbedded quartz-rich sandstone and arenaceous shale, which were deposited in the Williston Basin during the Middle Ordovician. The formation is thickest in southern Manitoba, reaching up to 75 m, and pinches out to the north (McCabe, 1978). The Winnipeg Formation unconformably overlies the Precambrian basement except in the southwestern corner of the province, where it overlies the Cambrian Deadwood Formation (Figure GS2024-22-1). The Winnipeg Formation is conformably overlain by the Ordovician Red River Formation (McCabe, 1978). The basal beds of the Red River Formation, called the Hecla beds, represent a gradational change between the two formations (McCabe, 1978).

The Winnipeg Formation has been subdivided into upper and lower units. The lower unit is characterized by a basal single-blanket sandstone that extends throughout the Williston Basin and is thickest (4.6 m) in southern Manitoba (McCabe, 1978). This basal sandstone is capped by a thick layer of shale, which is then overlain by transitions of discontinuous sandstone (Figure GS2024-22-2a). The lower unit was deposited in shallow marine, intertidal to deltaic environments during the early stages of a transgressive cycle (Vigrass, 1971). The upper unit consists of a basal shale bed that transitions into a sequence of interbedded sand-shale layers trending northward (McCabe, 1978). It has been interpreted to be deposited in offshore to nearshore environments (McCabe, 1978). The Carman Sand occurs within the upper unit and has been described as a vestigial offshore sandbar (Vigrass, 1971). The Carman Sand consists of a fine- to medium-grained, well-sorted, well-rounded silica sand that is unconsolidated (Figure GS2024-22-2b).

The lithogeochemistry of the Winnipeg Formation sand differs between lithofacies and spatially within the Williston Basin. The SiO_2 concentration within the lower unit varies with the highest content of 95.2–98.9% occurring near Seymourville (Watson, 1985; Lapenskie, 2016). However, samples of the lower unit collected from other sites had values as low as 61.1% SiO_2 (Lapenskie, 2016). The lithogeochemistry of the Carman Sand is not currently available.

The Winnipeg Formation outcrops along a thin north-south-trending margin at the eastern edge of the Williston Basin roughly following the boundary of the Precambrian shield. Outcrops of the lower unit are documented near Seymourville, including Grindstone Point, Hecla, Punk Island and Black Island. Disseminated boulders of the lower unit can be found in the Victoria Beach area. The Winnipeg Formation outcrops along the northern edge of the Williston Basin as well, specifically around the Wekusko Lake to Athapapuskow Lake area, west-central Manitoba (Lapenskie, 2016).

Methodology

Well and drillcore data from the Williston Basin Targeted Geoscience Initiative (TGI) database (TGI Williston Basin Working

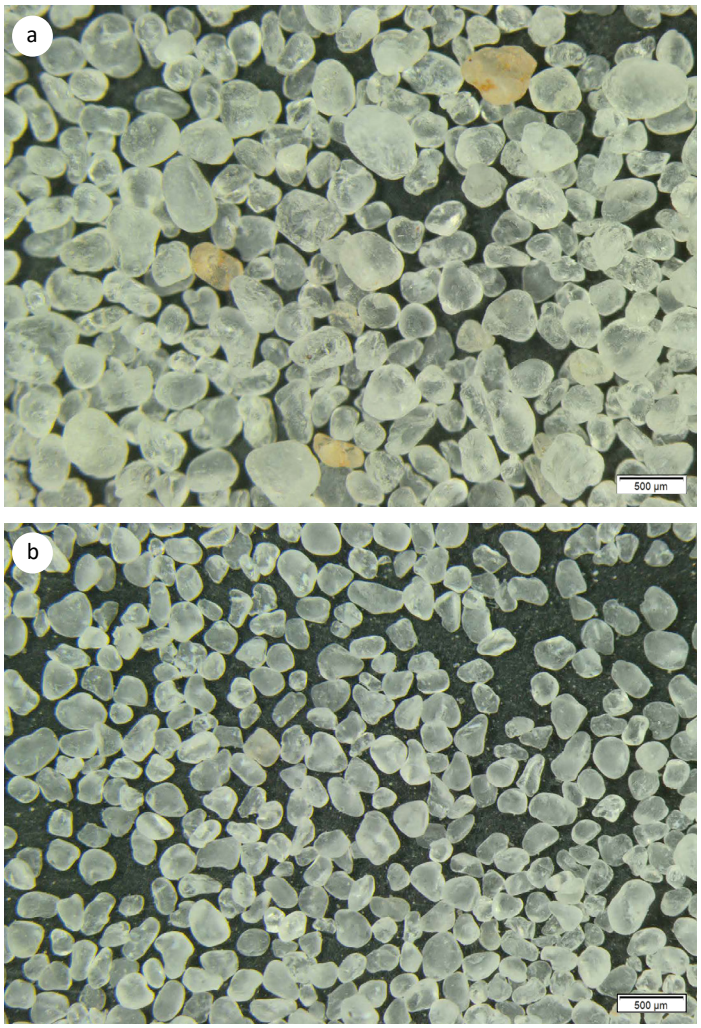


Figure GS2024-22-2: *Winnipeg Formation sand from* ***a)*** *the lower unit and* ***b)*** *the Carman Sand; note the abundant well-sorted, well-rounded silica grains in the Carman Sand.*

Group, 2008c) and the Manitoba Stratigraphic Database (MSD; Bezys and Conley, 1998) as well as borehole data extracted from assessment files in the Integrated Mining and Quarrying System (iMaQs; Manitoba Economic Development, Investment, Trade and Natural Resources, 2024) were compiled into a single dataset for this study. A series of isopach and structure maps were created using this dataset and were cropped to the Phanerozoic eastern edges of the Williston basin and to the region of interest (Twp. 1–30, Rge. 10E1–25W1) to focus on the area around the Carman Sand. Each map was computer generated using the Natural Neighbor tool in Esri® ArcGIS Pro. An isopach map of the upper unit without the Carman Sand data was constructed to identify the spatial boundary of the lens. A polygon of this area was made and then used to raster the maps of the Carman Sand to better constrain the sandbody.

Results

The Winnipeg Formation is thickest in the southern area of the province and has a distinctive east-west-trending lobate shape. The thickest section of the Winnipeg Formation is 75 m thick, northeast of the town of Melita. There are also thick areas of the Winnipeg Formation near the town of Ste. Rose du Lac. The Winnipeg Formation gradually thins toward the north but along the southeastern edge of Williston Basin it thins sharply. The isopach maps of the Winnipeg Formation constructed for this study are consistent with previously published TGI maps (TGI Williston Basin Working Group, 2008a).

For the lower unit, the thickest area occurs in south-central Manitoba close to the eastern boundary of the Williston Basin (Figure GS2024-22-3). The lower unit is 53.4 m thick south of the City of Winnipeg, with thick areas also occurring near the community of St. Marks and the town of Ste. Rose du Lac. There is distinctive thinning of the lower unit near the boundary of the overlying Carman Sand. The lower unit gradually thins along the edge of the Williston Basin except for the southeastern corner where it thins out abruptly.

The upper unit of the Winnipeg Formation thickens toward the southwestern corner of the province with the thickest (~75 m) near the town of Melita (Figure GS2024-22-4). The unit gradually thins to 5 m thick toward the edge of the Williston Basin. The upper unit also thins around the Carman Sand boundary and is particularly thin in patches south of the City of Winnipeg.

The Carman Sand is an asymmetrical teardrop-shaped lobe that trends east-west and narrows significantly toward the west (Figure GS2024-22-5). The lens is located exclusively in the south-central area of the province (Twp. 2–10, Rge. 8E1–16W1). Most of the lens is >20 m thick but can reach up to 34.7 m toward the eastern edge of the lobe, south of the City of Steinbach. There is a small patch of the Carman Sand approximately 33.4 m thick east of the local urban district of Ninette. The lens thins out along the northern and eastern boundaries but seems to abruptly truncate along the southwestern boundary.

The structure maps show that the Winnipeg Formation, its upper unit, the Carman Sand and its lower unit all dip toward the southwestern corner of the province. The Winnipeg Formation ascends to the surface toward the northern and eastern edges of the Williston Basin. The lower unit outcrops along this boundary, however, the Carman Sand pinches out before reaching the surface. The structure maps constructed for this project were consistent with previous research and didn't significantly differ from the TGI maps (TGI Williston Basin Working Group, 2008b).

Discussion

The isopach map of the Winnipeg Formation in this study is similar to previous research (McCabe, 1978) but by isolating each unit, clearer spatial differences between the upper and lower units, as well as the Carman Sand are apparent. Notably, the thickest part of the lower unit and the Carman Sand spatially coincide. However, the upper unit is thickest toward the southwestern portion of the province, where the Carman Sand pinches out. It is currently unclear if the thickened area of the lower unit

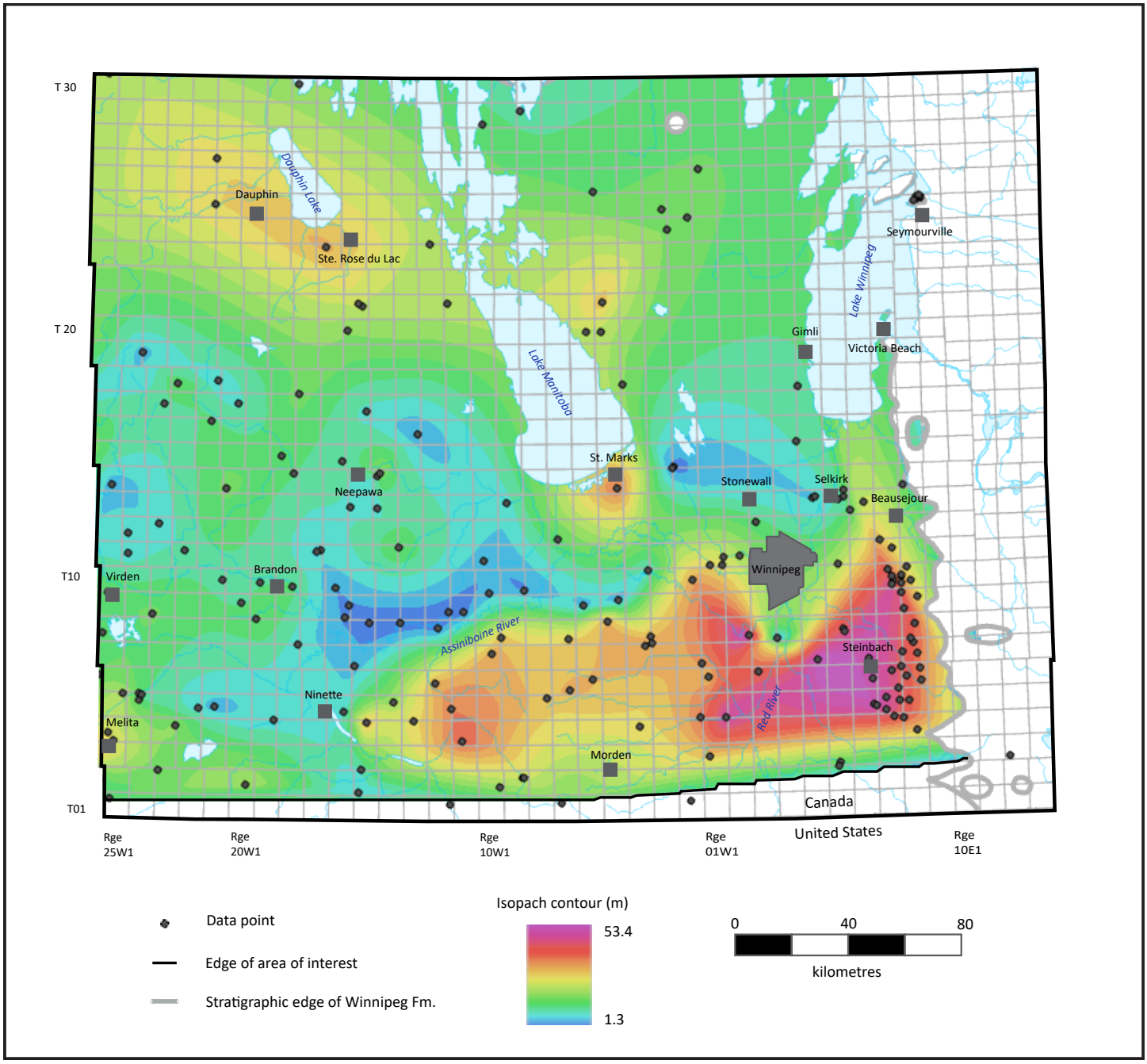


Figure GS2024-22-3: *Isopach map of the lower unit of the Winnipeg Formation in southern Manitoba. This preliminary map was constructed using a computer-generated model constrained to the project dataset. Data points from TGI Williston Basin Working Group (2008c). Basemap was created using ArcGIS® software 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/>.*

was also deposited as a vestigial sandbar, as proposed for the Carman Sand (Vigrass, 1971), or if there are other structural controls from the Precambrian basement affecting the spatial distribution of the Winnipeg Formation. The Carman Sand appears to be consistently more than 20 m thick, with the thickest area (34.7 m) toward the eastern edge of the lens near the City of Steinbach. The Carman Sand also thickens to 33.7 m at the western edge of the lens but is spatially smaller than the thickened area along the eastern edge.

Future work

Refined mapping and lithological control of the Carman Sand toward the western edge of its distribution is required to confirm its spatial distribution across southern Manitoba. With this additional data, a more detailed isopach map for the Carman Sand will be constructed. This map will help identify new areas of economic potential for high-quality silica sand. Further work characterizing the sand quality and lithogeochemistry of the Carman Sand will also be done. The basal sandstone bed of the lower unit

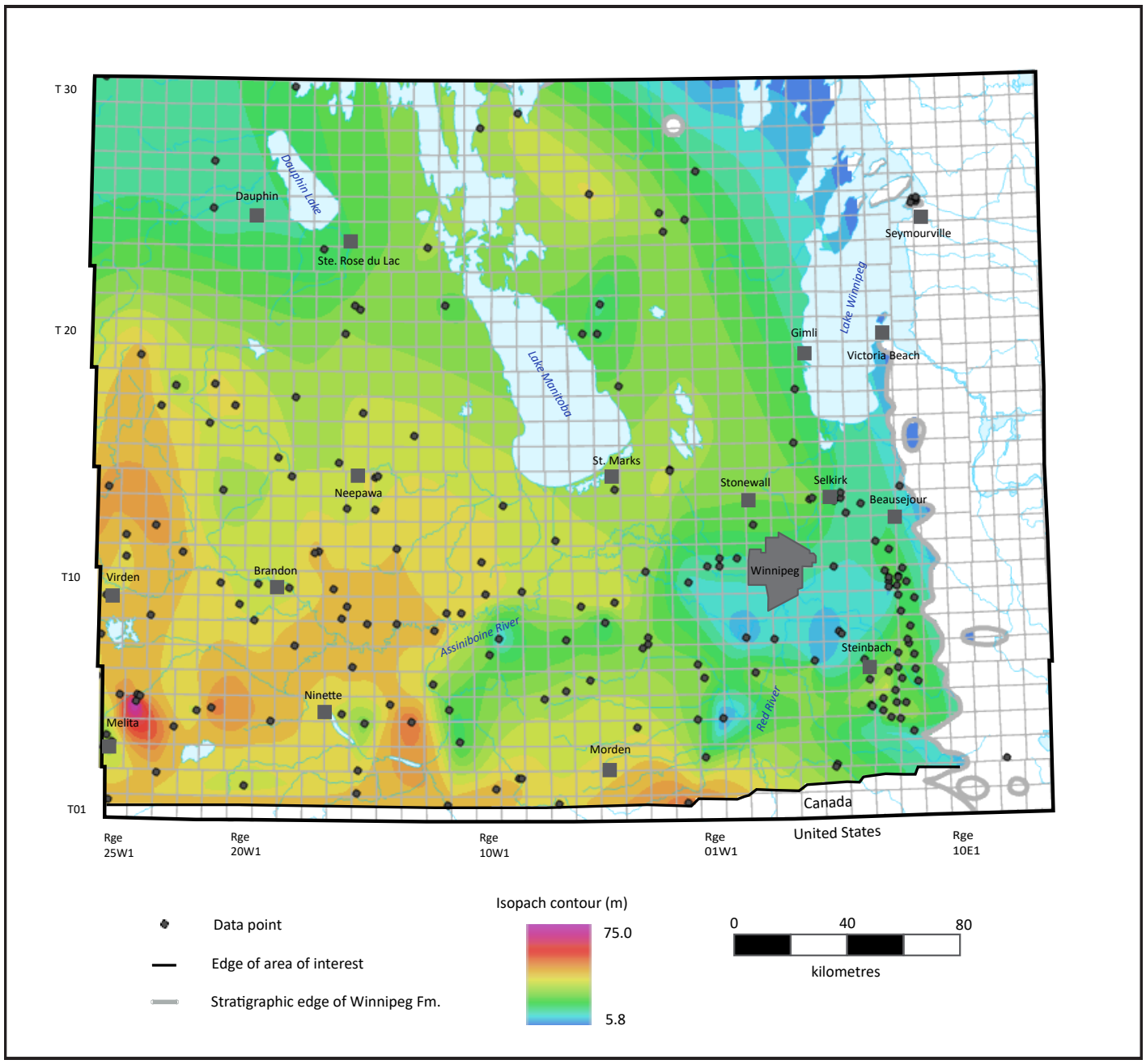


Figure GS2024-22-4: *Isopach map of the upper unit (including the Carman Sand) of the Winnipeg Formation in southern Manitoba. This preliminary map was constructed using a computer-generated model constrained to the project dataset. Data points from TGI Williston Basin Working Group (2008c). Basemap 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/>.*

is another potential economic source of silica sand and will be mapped to re-examine its distribution across Manitoba.

Economic considerations

Historically, the Winnipeg Formation has been extracted for glass production. However, silica sand has a wide range of industrial applications. In particular, recent development of the lower unit has focused on extracting this resource for solar panel production. The economic potential of the Carman Sand has also garnered interest. The high purity and quality of silica sand from the Carman Sand makes it an excellent candidate for producing high-quality proppant sand, which is currently in demand. As shown in this report, the distribution of the Carman Sand is irregular, therefore new mapping is needed to expand and refine the occurrence of this high-quality silica sand resource.

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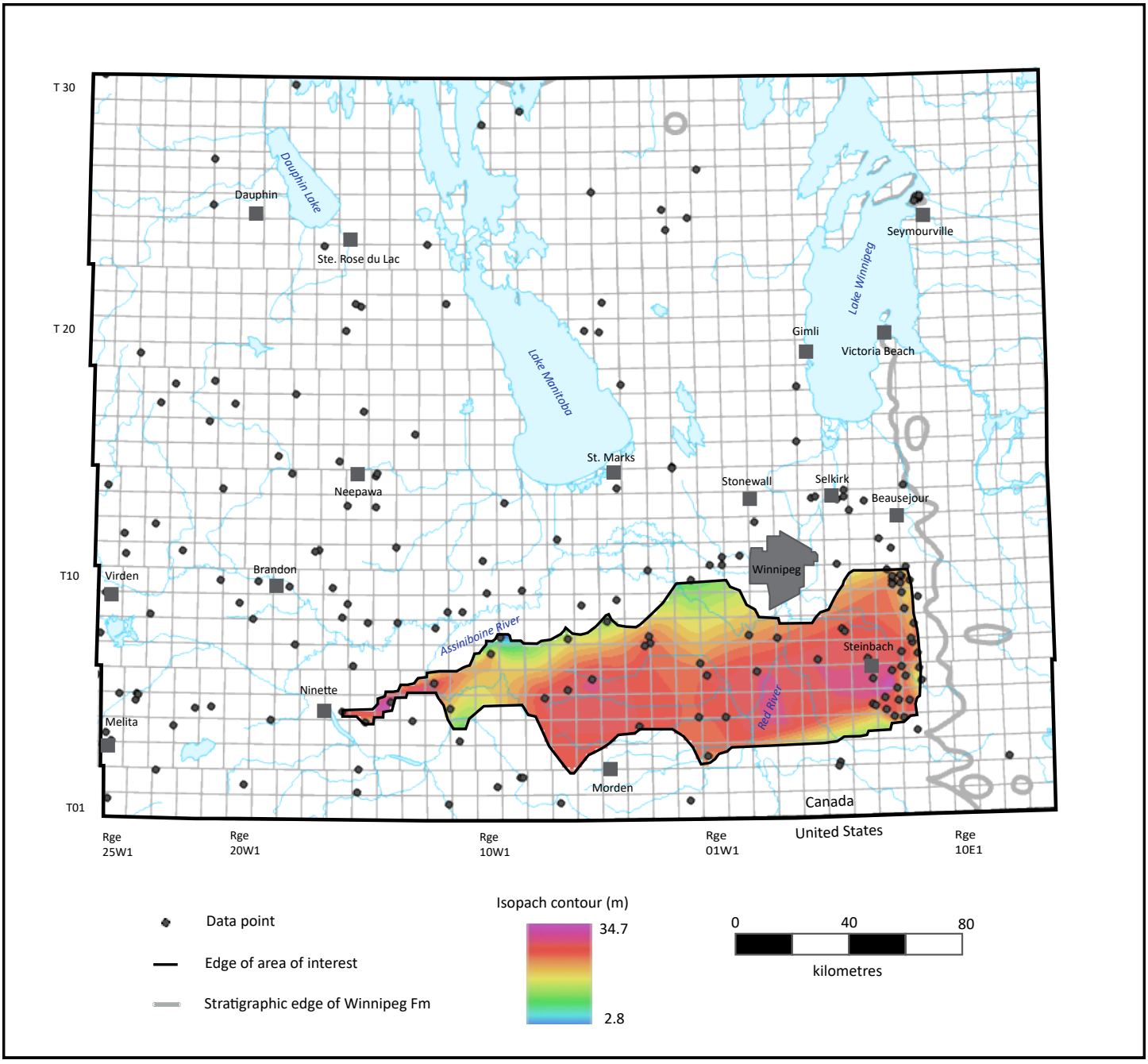

Figure GS2024-22-5: *Isopach map of the Carman Sand of the Winnipeg Formation in southern Manitoba. This preliminary map was constructed using a computer-generated model constrained to the project dataset. Data points from TGI Williston Basin Working Group (2008c). Basemap was created using ArcGIS® software 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/>.*

zoic geology, and H. Adediran for his help in constructing all the maps for this report. Reviews of this report were provided by P. Fraino and M. Nicolas.

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