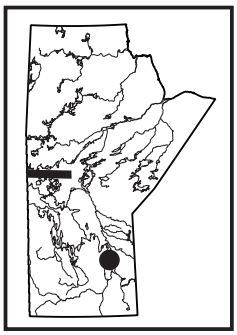
# GS-17 Preliminary investigations into the high-purity silica sand of the Winnipeg Formation, southern Manitoba

by K. Lapenskie



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## Summary

The Winnipeg Formation contains some of the purest silica sand in North America. Historically, this silica sand has been quarried and processed in the province to produce glass. The Manitoba Geological Survey is re-examining this formation to determine the economic potential of the silica sand for a variety of applications, including as a very high quality proppant for fracking. The $SiO_2$ content and the morphology of the sand grains will need to be defined for the various sandstone lithofacies of the Winnipeg Formation.

During the 2016 field season, reconnaissance fieldwork was done on exposures of the Winnipeg Formation in Hecla/Grindstone Provincial Park (including Black Island) and along the northern edge of the Williston Basin, in the vicinity of Wekusko to Athapapuskow lakes. Oil and exploratory drillcore from central and southern Manitoba are also being examined, as exposures do not offer complete sections of the Winnipeg Formation. Preliminary results from geochemical analyses of samples are presented in this report, along with general geological descriptions of the best exposed outcrops that were examined this year. Preliminary observations indicate a wide variability in the purity of the silica sand across the basin in Manitoba and within the different lithofacies of the Winnipeg Formation.

## Introduction

The high-purity silica sand of the Winnipeg Formation in Manitoba has many potential industrial uses. Historically, the sand has been quarried from Black Island to produce glass, and was processed in Winnipeg and later Selkirk.

In 2016, the Manitoba Geological Survey (MGS) initiated a project to examine the high-purity silica sand of the Winnipeg Formation, with a focus on the potential of this silica sand to be the highest quality proppant for the fracking industry. To determine the industrial potential of the Winnipeg Formation, several objectives must be achieved:

- compile detailed geological descriptions of outcrops and drillcore to correlate lithofacies variations across the subcrop–outcrop belt of the Williston Basin;
- determine the quality of the silica sand as it pertains to the various lithofacies through geochemical analyses and quantitative descriptions of the character of the sand grains; and
- create isopach and structure contour maps where necessary using drillhole and water well data.

The 2016 field season was focused primarily on reconnaissance of the Winnipeg Formation outcrops in Hecla/Grindstone Provincial Park and along the northern edge of the Williston Basin. However, it should be noted that exposures of this formation in Manitoba do not offer complete sections. Therefore, exploration and oil drillcore were also examined to observe complete sections of the Winnipeg Formation and will be correlated with the outcrop sections to put it all into stratigraphic perspective.

## Regional geology

The Winnipeg Formation occurs in southwestern Manitoba at the base of the Williston Basin strata. It comprises the oldest Ordovician rocks in Manitoba and is the oldest outcropping Phanerozoic rock in the province. The formation nonconformably overlies Precambrian bedrock, except in the southwestern corner of Manitoba where it unconformably overlies the Cambrian Deadwood Formation (McCabe, 1978). The Winnipeg Formation is overlain by the Red River Formation. The Winnipeg Formation was deposited during a major transgressive cycle in the Williston Basin during the mid- to late-Ordovician (Vigrass, 1971).

The Winnipeg Formation is subdivided into upper and lower units, with a vestigial offshore sandbar, termed the Carman sand, occurring between these units in southern Manitoba (Vigrass, 1971; Nicolas, 2008). The formation is composed of quartz-rich sandstone and variably arenaceous mudstone. During the early stages of the transgression, the lower unit was deposited in relatively shallow conditions, ranging from shallow marine, intertidal to deltaic, and is composed primarily of sandstone (Vigrass, 1971). The upper unit is composed of varying amounts of sandstone to mudstone, and is interpreted as being deposited in deeper marine to shallow marine and possibly terrestrial environments (McCabe, 1978). The maximum thickness of the Winnipeg Formation is 60 m.

## Preliminary work

During the 2016 field season, select outcrops were examined in Hecla/Grindstone Provincial Park and along the northern extent of the Williston Basin (Figure GS-17-1). The outcrops at Grindstone Point and on Black Island,

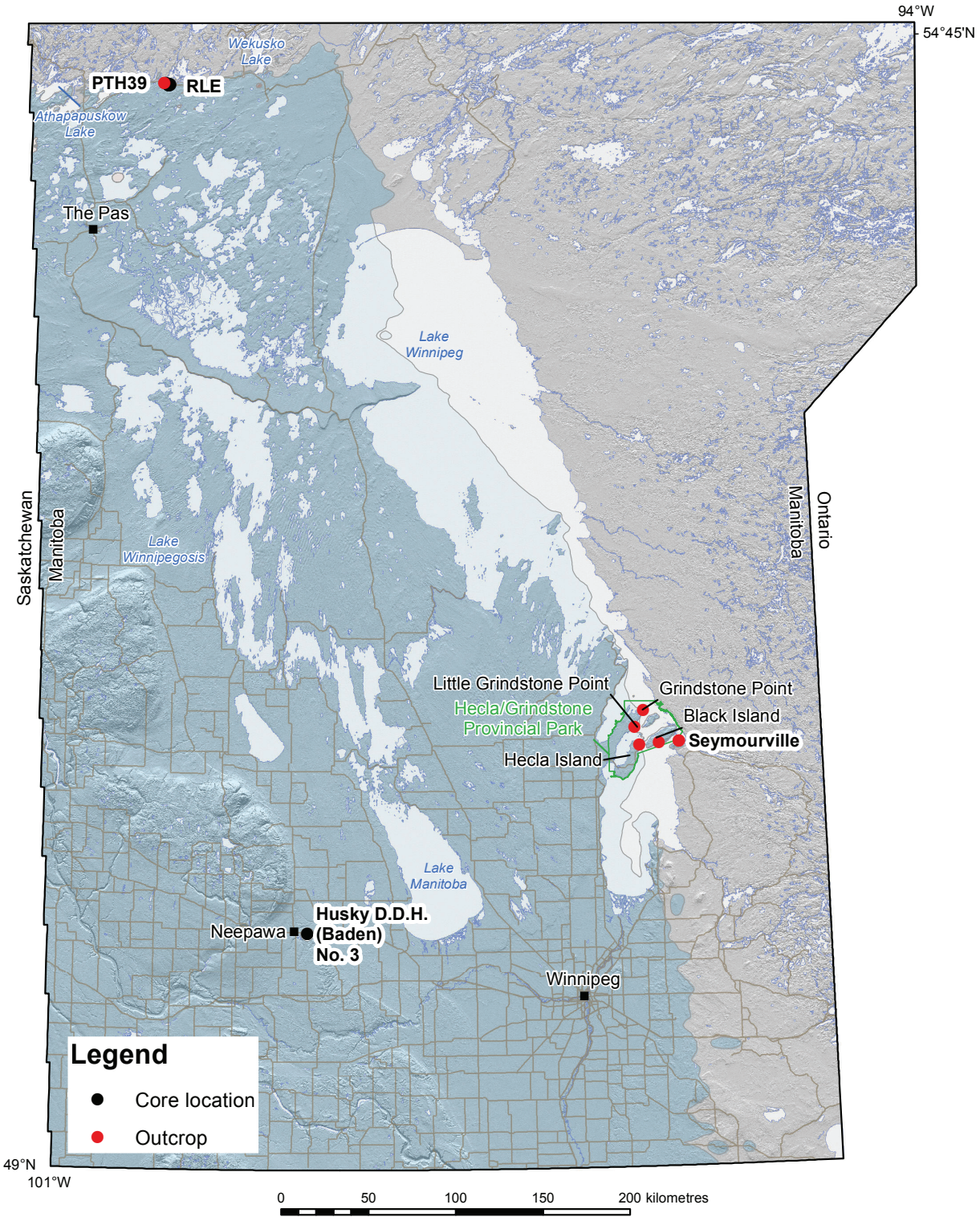


***Figure GS-17-1:*** *Map of the Winnipeg Formation in southern Manitoba; extent in light blue. Locations of cores and best exposed outcrops are identified. Hecla/Grindstone Provincial Park is outlined in green. Abbreviation: RLE, Reed Lake exploration.*

both in Hecla/Grindstone Provincial Park, were selected for accessibility and economic importance, as the Black Island silica sand has historically been quarried. Outcrops do not offer complete exposures of the Winnipeg Formation, therefore oil and exploration drill core are being examined to understand how the purity of the silica sand varies across the basin and within different lithofacies.

Samples from an outcrop at Seymourville and from five exploration and oil drillcores in southern and west-central Manitoba (Figure GS-17-1) were submitted for whole-rock geochemical analysis.

### *Black Island, Hecla/Grindstone Provincial Park*

The silica sand quarry on the south shore of Black Island is still accessible and possesses some of the best exposures of the Winnipeg Formation in Manitoba. The outcrops on Black Island and elsewhere in Hecla/Grindstone Provincial Park are of the lower unit (McCabe, 1978; Watson, 1985). The maximum thickness of the section is approximately 7.8 m. The silica sand is poorly consolidated, and much of the exposures in the quarry are covered with slumped material.

Two major lithological units occur on Black Island, a lower sandstone unit overlain by a pyritic shale. The sandstone is up to 6.2 m thick, and is composed of bedded to cross-bedded, burrowed, grain-supported, quartz arenite (Figure GS-17-2). The weathered sandstone is pale yellow, whereas fresh exposures are golden yellow to orange-brown. A kaolinitic matrix comprises <5% of the total rock. The sand is composed entirely of well rounded to rounded, equant, very coarse to fine-grained quartz grains. The sandstone is uncommonly calcareous. A single, prominent, cross-stratified bed is present in the lower portion of the section (Figure GS-17-2). The upper contact with the shale is sharp; the basal contact with the Precambrian basement was not observed.

The overlying unit is composed of a pyritic, bedded to laminated shale. The weathered shale is light to medium grey, and fresh surfaces are dark grey. In places, the shale is composed of up to 50% pyrite nodules, which are rounded, equant to elongate, concentrically layered, and 0.5–1.0 mm in diameter.

### *Hecla/Grindstone Provincial Park: additional sites*

The Winnipeg Formation is exposed on several other islands and also in places along the Grindstone Point shoreline within Hecla/Grindstone Provincial Park (Figure GS-17-1). Exposures of the Winnipeg Formation were observed at Grindstone and Little Grindstone points and along the northern shoreline of Hecla Island. The Winnipeg Formation attains a maximum thickness of 1.4 m in this area, although the base of the sections observed were covered with slumped material.

Exposures of the Winnipeg Formation only contained a single unit of sandstone. The sandstone is composed of massively bedded, pyritic, variably calcareous, quartz arenite (Figure GS-17-3). The sandstone weathers to buff, with fresh surfaces yellow and often mottled orange. Pyrite nodules occur concentrated in irregular laminations. The sand is composed of well sorted, well rounded, equant, predominantly fine-grained quartz grains. The upper contact with the Red River Formation is sharp; the basal contact with the Precambrian basement was not observed.

### *Northern edge of the Williston Basin*

There are few outcrops of the Winnipeg Formation in the Wekusko Lake to Athapapuskow Lake area, and more fieldwork is needed in the area to identify any substantial sections. Very thin beds of the Winnipeg Formation were observed at the base of quarries and Red River Formation sections; the partially consolidated nature of the Winnipeg

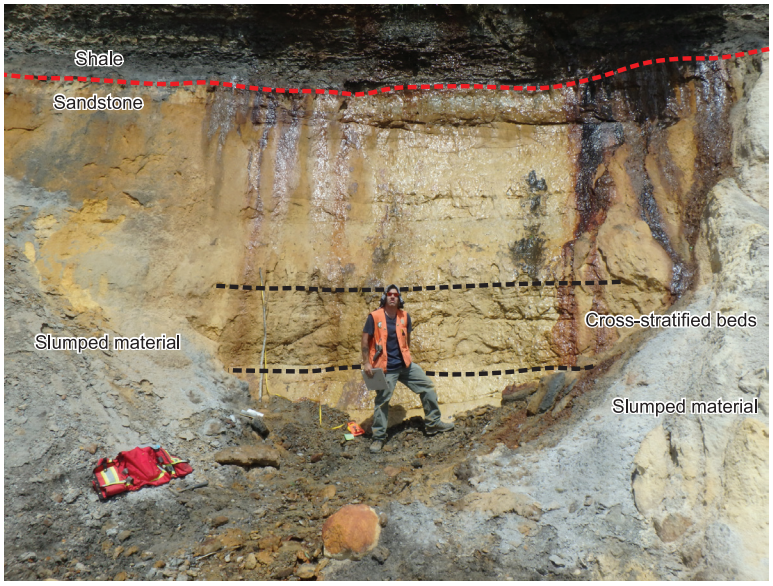


***Figure GS-17-2:*** *Section of the Winnipeg Formation in the Black Island quarry. Cross-stratified bed is approximately 1.75 m thick. Slumped sand from the lower unit occurs on either side of the exposure. Sulphide staining is visible below the contact between the lower sandstone and upper shale.*

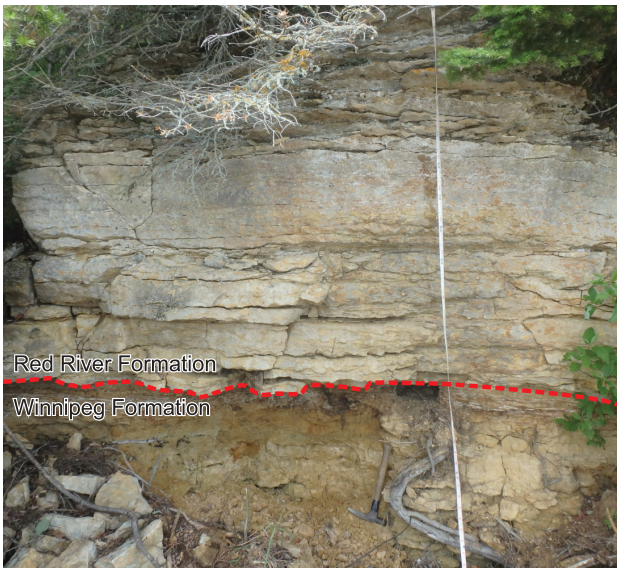


***Figure GS-17-3:*** *Section of the Winnipeg and Red River formations at Little Grindstone Point in Hecla/Grindstone Provincial Park. The upper contact of the Winnipeg Formation is visible.*

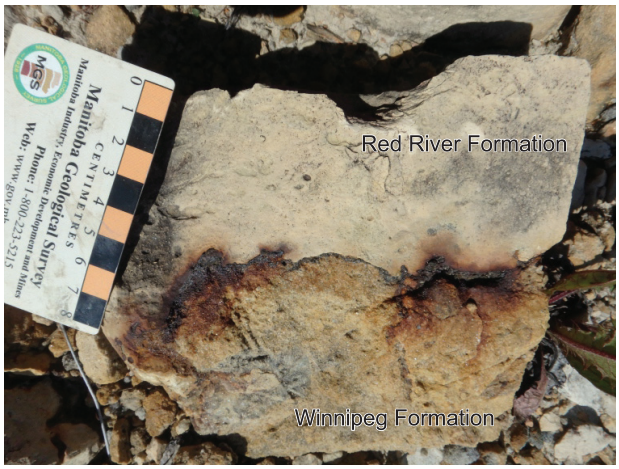


***Figure GS-17-4:*** *Displaced boulder showing the contact between the Winnipeg and Red River formations in the ditch along PTH 39. Note the abundant disseminated sulphides along the contact, concentrated within the sandstone of the Winnipeg Formation.*

Formation results in the exposures being highly weathered, often mixed with surficial material.

Along Provincial Trunk Highway (PTH) 39, a relatively recent excavation of the ditch adjacent to the road resulted in large blocks of the Winnipeg Formation being exposed (Figure GS-17-1). Despite these boulders being out of original position, they provided excellent examples of the contact between the Winnipeg and Red River formations in this region. Disseminated sulphides are abundant in the uppermost Winnipeg Formation and along the upper contact with the Red River Formation (Figure GS-17-4). These sulphides strictly occur in the Winnipeg Formation at this locality. The Winnipeg Formation is composed of massive, fossiliferous, pyritic quartz arenite. The sand is composed of moderately to poorly sorted, rounded to angular, equant to tabular, fine- to gravel-sized quartz grains. The formation is yellow to dark orange-brown where sulphides are abundant. The matrix is composed of kaolin, pyrite and possibly silica, and comprises approximately 5% of the sandstone. Large gastropods, receptaculitids and ichnofossils are common in the sandstone.

## Whole-rock geochemistry

Samples of silica sand taken from an outcrop near the community of Seymourville, exploration drillcore from Reed Lake and an oil drillcore near Neepawa (Figure GS-17-1) were sent for lithogeochemical analyses to determine the concentrations of silica and other major elements. The MGS acquired several exploration drillcore, from HudBay Minerals Inc. (A. Bein, pers. comm., 2015), that penetrated the Winnipeg Formation in the Reed Lake area; the exact locations of these cores cannot be released at this time. The Seymourville sample was collected from a roadside exposure (UTM Zone 14, 687108.59E, 5673346.22N) and was also run as a duplicate sample. The lower unit was sampled from Husky D.D.H. (Baden) No. 3 (Husky) oil drillcore (Assessment File 92826, Manitoba Growth, Enterprise and Trade, Winnipeg) from L.S. 15, Sec. 29, Twp. 14, Rge. 14, W 1st Mer. The Reed Lake cores, Husky core and Seymourville samples are widely geographically separated and from different stratigraphic levels within the Winnipeg Formation.

## Preliminary results

Results of the lithogeochemical analysis of the Winnipeg Formation sand samples are presented in Table GS-17-1. The purity of the silica sand is variable among samples, with the purest sample having a silica content of 98.89% and the least pure sample having 61.07%. In general, the Reed Lake core samples have a lower silica content; sulphides and carbonate matrix were common in the Winnipeg Formation in these cores. Significant processing of the sand from the Reed Lake area would be required to upgrade its purity. The Seymourville sample had the highest purity of all samples submitted. The Husky core has a relatively moderate amount of silica at 87.43%; this core was from much deeper in the Williston Basin. These results tentatively indicate a wide variability in the purity of the silica sand across the basin in Manitoba and within the different lithofacies of the Winnipeg Formation.

**Table GS-17-1:** Lithogeochemical results of samples from the Winnipeg Formation. The depth at which the sample was collected from the specific core is noted at the end of the sample number. Sample 114-16-Husky is from Husky D.D.H. (Baden) No. 3 drillhole (Assessment File 92826, Manitoba Growth, Enterprise and Trade, Winnipeg). See Figure GS-17-1 for sample locations. Sample 114-16-RLE037, 14.9 m, was the only sample to be washed with Calgon™ to remove excess clay- and silt-sized particles.

| Sample number | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MnO | CaO | $Na_2O$ | $K_2O$ | $TiO_2$ | $P_2O_5$ | LOI | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 114-16-Seymourville_1 | 98.10 | 0.56 | 0.86 | 0.005 | 0.03 | <0.01 | 0.15 | 0.082 | <0.01 | 0.59 | 100.40 |
| 114-16-Seymourville_2 | 98.89 | 0.50 | 0.69 | 0.004 | 0.03 | <0.01 | 0.13 | 0.065 | <0.01 | 0.51 | 100.90 |
| 114-16-RLE037, 14.9 m | 65.59 | 15.49 | 2.19 | 0.011 | 0.18 | 0.21 | 10.03 | 0.699 | 0.09 | 3.77 | 99.70 |
| 114-16-RLE037, 15.2 m | 87.45 | 4.93 | 2.66 | 0.017 | 0.07 | <0.01 | 2.82 | 0.120 | <0.01 | 1.45 | 100.90 |
| 114-16-RLE038, 8.5 m | 69.68 | 0.67 | 7.31 | 0.034 | 9.27 | <0.01 | 0.36 | 0.047 | 0.02 | 9.82 | 98.63 |
| 114-16-RLE038, 9.04 m | 64.41 | 1.15 | 1.26 | 0.026 | 18.28 | <0.01 | 0.27 | 0.203 | <0.01 | 14.45 | 100.70 |
| 114-16-RLE040, 8.42 m | 65.13 | 0.46 | 2.21 | 0.054 | 9.62 | 0.01 | 0.11 | 0.074 | <0.01 | 14.95 | 98.94 |
| 114-16-RLE040, 11.0 m | 84.76 | 4.21 | 2.35 | 0.031 | 1.37 | 0.29 | 0.65 | 0.243 | <0.01 | 3.28 | 98.53 |
| 114-16-RLE042, 25.35 m | 61.07 | 0.46 | 2.64 | 0.048 | 11.33 | <0.01 | 0.18 | 0.059 | <0.01 | 16.27 | 98.97 |
| 114-16-RLE042, 25.95 m | 91.31 | 0.85 | 1.01 | 0.017 | 2.08 | <0.01 | 0.18 | 0.218 | <0.01 | 3.29 | 100.20 |
| 114-16-Husky, 762.76 m | 87.43 | 2.07 | 1.43 | 0.010 | 2.60 | 1.02 | 0.17 | 0.098 | <0.01 | 5.60 | 100.50 |

Abbreviations: LOI, loss on ignition; RLE, Reed Lake exploration.

## Economic considerations

The Winnipeg Formation has previously been used to create glass in Manitoba. This high-purity silica sand remains a possible source of foundry sand. The Winnipeg Formation has a high potential for being a source of very high quality fracking sand. Other potential uses of the silica sand include creating silicon carbide, silicon metal and enamels. Geological investigations into the quality and purity of this silica sand as it pertains to the various lithofacies changes across the Williston Basin will help guide industry in selecting areas of high economic potential.

## Acknowledgments

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