Shallow unconventional Cretaceous shale gas in southwestern Manitoba

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Introduction

Shallow shale gas occurrences have been recorded in Manitoba for over a century, but understanding of and geoscientific data on this potential economic resource are limited (Figure 1). The goal of the Shallow Unconventional Shale Gas Prospects Project is to help address some of these issues, by providing potential investors with the basic information they need to undertake exploration in the new and risky shallow unconventional shale gas plays. The current project is targeting the Cretaceous formations, including the Ashville, Favel, Carlile and Pierre formations (Figure 2), located in the southwest corner of Manitoba, roughly following the Ashville Formation outcrop edge and the Manitoba Escarpment edge.

The goal of the project is to summarize the shallow shale gas prospects for Manitoba, characterize the gas, define the area of gas occurrance, and identify intervals within prospective formations with the greatest potential to contain gas.

The source of the shallow shale gas in Manitoba is likely biogenic, formed by in situ biodegradation of organic matter, however there is still a possibility that the gas may be thermogenic in places. This microbiological activity is hypothesized to have been rejuvenated by an inflow of fresh water after the retreat of the glaciers (Grasby, pers. comm., 2008), suggesting a late-generation gas system (Shurr and Ridgley, 2002), while the geology and age of the Cretaceous shale sequence suggest the gas may be early-generation gas system. Producing late-generation gas is typically associated with a high water production, while early-generation gas is water sensitive and so water should be avoided during drilling and completing. Alternatively, the gas could be a hybrid between early and late generation gas, as well as a hybrid of biogenic and thermogenic gas. Understanding the type of the gas is important in designing exploration programs as well as customizing drilling programs to the target formations.

Project Details

The Shallow Unconventional Shale Gas Prospects Project is a multi-year investigation of shallow gas potential in Manitoba's upper Cretaceous shale sequences, particularly the Ashville, Favel, Carlile and Pierre Shale formations (Figure 2).

The first year of the project was focused mainly on collecting shale, water and gas samples from locations south in the southern portion of the study area. The outcrop sampling was limited to the Pembina Hills and Pembina Valley region (between Treherne and the USA border), and the core sampling was limited to wells south of township 13.

The second year of the project will focus mainly on collecting shale samples from locations in the northern half of the study area, and will include subsurface data collection from township 1 to 44. The outcrop sampling will be focused in the Riding Mountain, Duck Mountain and Porcupine Hills regions. Miscellaneous data collection from the southern half will continue.

A series of analytical methods have been employed in the first year, and will continue into the second and third years. To date, Rock-Eval and TOC was conducted on 87 new outcrop and core samples collected in the first year, and the results were compiled with archive data from Nicolas (2009) and Obermajer et al. (2005). X-ray Diffraction (XRD) was conducted on 47 of the new samples. Major and trace element bulk geochemistry will be conducted on outcrop samples.

Year 1 Fieldwork

The first year of fieldwork was conducted to sample Late Cretaceous shale from the Pembina Hills and Pembina Valley region in southwestern Manitoba, shown in Figure 1. A total of 36 individual field sites were examined and sampled, representing four east–west stratigraphic transects through the Pembina region's outcrop formations, which include the Favel, Carlile and Pierre Shale formations (Figure 3). Selected samples will be sent for various geochemical and mineralogical analyses, as mentioned above.

Additional fieldwork was conducted to collect water and free gas samples from domestic wells (Figure 4). A total of two gas wells and 13 water wells were sampled. The Geological Survey of Canada in Calgary (GSC-C) is analyzing the water samples for dissolved solids, alkanity and sulphate. Also, both the water and free gas samples were analyzed for gas composition and various stable isotopes.

Lithological variations were notable within some of the formations, particularly the Boyne Member of the Carlile Formation and the Odanah Member of the Pierre Shale. In contrast, the Morden Member of the Carlile Formation and the Pembina and Millwood members of the Pierre Shale no lithological variations were observed in their sections, except for numerous bentonite seams within the Pembina Member.

Most outcrops sampled are uniform fissile shale. One roadside outcrop in the Boyne Member (located in the Snow Valley along Roseisle Creek southwest of Roseisle, Manitoba); however, contains a 2 m thick, shaly siltstone bed underlain by a dark black shale and topped by a medium brown shale. The shaly siltstone, being more resistant to weathering than the overlying and underlying shale beds, stands out prominently in the roadcut (Figure 3a). This resistant unit can be subdivided into a lower shaley siltstone, and an upper shaley siltstone to sandstone. Possibly due to its resistant character, this unit is characterized by abundant centimetre-scale, horizontal and vertical fracturing, as well as decimetre- to metre-scale jointing. The lower shaly siltstone is calcareous, and displays internal bedding, crossbeds, thin laminae, and lenses of siltstone to fine sandstone (Figure 3b). The upper shaly siltstone to sandstone is similar to the lower unit, but contains thin beds and lenses of fine sandstone throughout. One quarry outcrop northeast of Notre Dame de Lourdes along the Manitoba Escarpment edge, contains a thin siltstone bed in the upper Boyne Member; its exact stratigraphic position relative to the Roseisle Creek outcrop is uncertain.

The discovery of siltstone beds within the Boyne Member is significant because it indicates that porous gas-bearing siltstone beds are present in Manitoba. The extension of the siltstone beds into the subsurface, where they can serve as a gas reservoir, has yet to be investigated in full, but preliminary log analysis indicates that they extend westward to the Saskatchewan border.

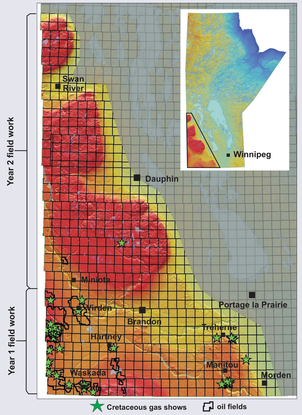

Figure 1: Digital elevation model showing the study area of the Shallow Unconventional Shale Gas Prospects Project, the location of Phase 1 and Phase 2 of the project, Mesozoic and Cenozoic gas shows in relation to extisting oil fields, field station and water/gas sampling sites of the 2008 sampling program.

SOUTHWESTERN MANITOBA		
CRETACEOUS	Pierre Shale	Coulter Member
		Odanah Member
		Millwood Member
		Pembina Member
		Gammon Ferruginous Member
	Carlile Formation	Boyne Member
		Morden Member
	Favel Formation	Assiniboine Member
		Keld Member
	Ashville Formation	Belle Fourche Member
		Westgate Member
		Newcastle Member
		Skull Creek Member

Figure 2: Stratigraphic column of southwestern Manitoba showing the target formations for this study; highlighted members have documented gas shows.

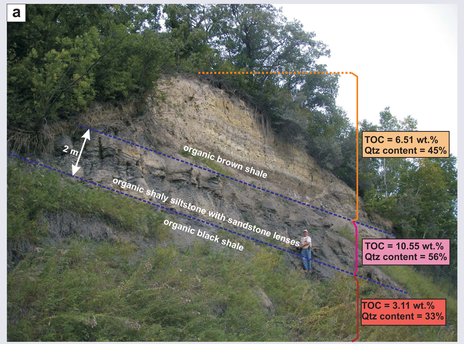

Figure 3: Summer 2008 field work photos showing outcrop of a excellent source and reservoir rocks exposed at a road cut: **(a)** outcrop of the lower to middle section of the Boyne Member in Snow Valley, near the town of Roseisle, with organic shaly siltstone and sandstone beds more resistant to weathering than the overlying and underlying shale; and **(b)** close-up of outcrop in (a), showing the shaly siltstone bed with sandstone lenses. TOC and average quartz contents for each sequence is indicated.

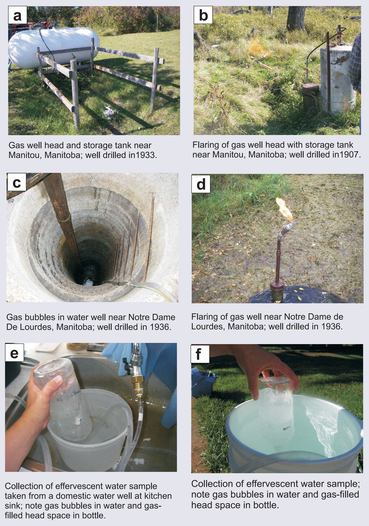

Figure 4: Series of six photographs taken during the collection of water and gas samples.

Organic Geochemistry

Rock-Eval 6 ®/TOC was conducted on all the outcrop samples collected to date, and the results were compiled with historical Rock-Eval/TOC databases from Nicolas (2009) and Obermayer et al. (2005). The compiled data was then filtered to eliminate false results; in some cases this completely eliminated the Odanah and Millwood members from the charts due to the extreme immaturity of the sediments and low organic content. Figure 5 shows some of the preliminary results from this geochemical compilation subdivided by member.

The Tmax and TOC results indicate that the shale formations have not reached thermal maturity, but most of these rocks are good to excellent source rocks, respectively. Despite the immaturity of the sediments, the Production Index plot several shale members into the thermogenic window. This is due to the high concentration of free or adsorbed gas in the system, suggesting a biogenic origin.

The modified van Krevelen diagram is used to distinguish kerogen types, with some shales plotting between the Type II and Type III kerogen lines, and some below the Type III line (Figure 6). This sort of signature is expected, particularly with an abundance of points below the Type III kerogen line, due to the overall immaturity of these sediments, particularly as the sediment become younger.

These preliminary results suggest the Ashville Formation Belle Fourche Member, Favel Formation and Carlile Formation, particularly the Boyne Member, are the best targets for shallow shale gas exploration.

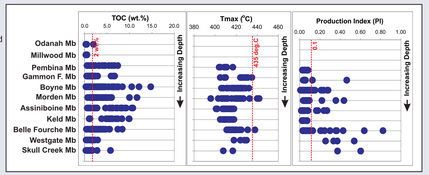

Figure 5: Rock-Eval results grouped by member and placed in order of increasing stratigraphic depth. The red line in the TOC graph equals 2 wt. %, which indicates the preferred minimum TOC value for a good source rock. The red line in the Tmax graph equals 435 degrees Celcius, which corresponds to the oil window for mature oils. The red line in the Production Index graph equals 0.1, which indicates the minimum PI value for thermogenically derived oil and gas.

Gas Chemistry

Dissolved and free gas compositions were measured for all the water and gas samples collected. Figure 7 shows five samples with high methane values. Air contamination and methane loss by degassing during the sample collection is likely the cause for the increased nitrogen in the samples.

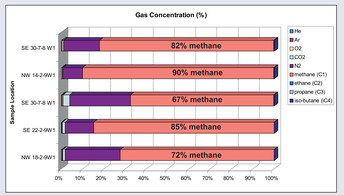

Figure 7: Gas compositions for five samples collected in the Pembina Hills region. The two top samples are free gas compositions from samples taken from gas wells, and the lower three samples are dissolved gas compositions taken from domestic water wells. Samples from township. 7 range 8W1 are from the Notre Dame de Lourdes area, and samples from township 2 range 9W1 are from the Manitou area.

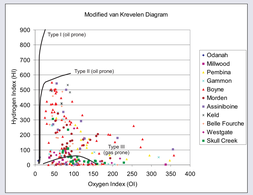

Figure 6: Modified van Krevelen diagram of new and archival Rock-Eval data grouped by member.

Inorganic Geochemistry

To assist in the mineralogical analysis of Manitoba's Cretaceous shale sequences in southwestern Manitoba, a review of historical whole rock and trace element analyses was initiated. The results of the whole rock and trace element search is available in Bamburak (2008). Future work will involve the compilation and integration of major and trace element distribution by formation, member and/or bed from oil company exploration core and outcrops, also described in Fedikow et al. (1998). To date, the literature search has revealed that there are many gaps in the whole rock and trace element geochemical knowledge of the Cretaceous stratigraphic package. The sampling carried out during year 1 will go a long way to addressing these deficiencies in the Manitoba Geological Survey's chemostratigraphic database.

Shown below in Figure 8 are two examples of selective retrievals of data contained in the chemostratigraphic database of major and trace elements of outcrop samples collected several years ago in the Year 1 fieldwork area (Fedikow et al., 1998).

Various information can be determined from elemental data contained in the chemostratigraphic database. Using the database, it should be possible to separate geological units by their distinctive geochemical signature where stratigraphic control is weak or absent. It is also speculated that as more data becomes available that it may be possible to determine, which elements might be diagnostic in the search for shallow gas resources. The presence of shale gas might be accompanied by the relative increase or decrease in certain elements compared to the "normal" chemistry of the formation, member or bed; and this could become a tool for its detection.

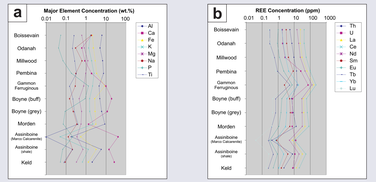

Figure 8: Chemostratigraphy of the Late Cretaceous, based on selective retrievals of data from the chemostratigraphic database of (a) major and (b) trace elements (REE) of outcrop samples.

Mineralogy

X-ray diffraction (XRD) was conducted on a select suite of 47 samples collected from outcrops. Samples were analysed if they had a TOC > 2 wt%, in addition to all the Odanah Member samples due to its siliceous character. Figure 9 shows an averaged mineralogy distribution for the samples. Of particular interest is the high quartz content of the shale sequences. With the XRD results, the averaged mineralogy is misleading, since upon closer analysis at the individual results, the Boyne Member, which shows an average of ~35% quartz on the graph, actually has quartz contents ranging from 8% to 89%.

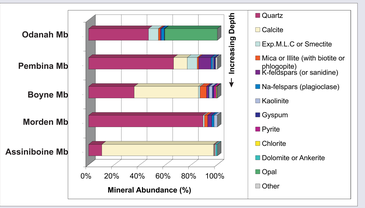

Figure 9: Averaged XRD results grouped by member.

Historical Gas Exploration

Gas exploration was active in Manitoba from 1906 to ~1933, after domestic water well drilling routinely hit gas pockets. Wallace and Greer (1927) reported that natural gas was being used for domestic lighting and cooking purposes at several sites in southwestern Manitoba. Kerr (1949) documented eleven gas well localities, including those of Wallace and Greer. These natural gas occurrences can generally be grouped into the Miniota, Treherne, Manitou, and Waskada-Sourisford areas. In the Manitou area, two gas wells drilled during era still remain capped today, feed adjacent tanks, and have initial pressures of 276 kPa (Figure 4a and 4b). In the Notre Dame de Lourdes area (east of Treherne), one water well drilled in c.1930 has been converted to a gas well with the attachment of gas nozzle; this well has an initial pressure of 221 kPa (Figure 4c and 4d).

Modern Gas Exploration

Modern exploration for shallow shale gas in Manitoba has been ongoing since 2003, with EOG Resources Canada Inc. drilling three shallow wells (10-17-1-24W1, 3-27-1-25W1 and 1-3-2-25W1) in the Waskada Field and perforating them in the Assiniboine Member of the Favel Formation. Unfortunately, these wells produced only water and were subsequently abandoned. Preliminary evaluation of these wells suggests that formation damage during drilling may have been the reason for the lack of gas production.

In 2006–2007, Tundra Oil and Gas Partnership drilled three wells (4-6-4-29W1, 2-11-4-29W1 and 8-29-4-29W1) to test the Cretaceous shale. The 4-6-4-29W1 well was abandoned after a short distance of 348.0 m, terminating in the Millwood Member of the Pierre Shale. The other two wells were terminated in the Fish Scale interval of the Belle Fourche Member of the Ashville Formation; both wells were cored in the Boyne Member of the Carlile Formation. No production has yet been reported, but a small flame can be ignited from the well. Formation damage during drilling is also suspected to have damaged the reservoir in these wells.

Economic Considerations

Despite a long history of oil and gas exploration in Manitoba, unconventional shallow gas prospects are still poorly understood. The goal of the Shallow Unconventional Shale Gas Prospects Project is to provide potential investors and companies with the basic information needed to undertake exploration in the new and risky unconventional shallow shale gas plays in southwestern Manitoba. Since the potential area for shallow gas production is large, extending from the Manitoba Escarpment west to the Saskatchewan-Manitoba border and from the Porcupine Hills south to the Canada–United States border, economic benefits—if resources are present—could be significant.

Conclusions

Manitoba has a vast shale gas resource that has not been adequetly explored with modern technology. Early results from this study are encouraging. The combination of shale with thick siltstone and sandstone beds, documented gas shows, low Tmax values, high TOC contents and high quartz fractions within the Boyne Member of the Carlile Formation indicate that Manitoba has the right geological conditions for the generation of unconventional shallow shale gas of biogenic origin.

The best Cretaceous shale gas targets in Manitoba are the Carlile Formation, particularly the Boyne Member, Favel Formation and Belle Fourche Member of the Ashville Formation. Further analyses and field work will be conducted in 2009-2010 to continue this investigation and further our knowledge of Manitoba's shale gas prospects.

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