Introduction

Over the last three years, the Shallow Unconventional Shale Gas Project has focused on southwestern Manitoba's Cretaceous shale sequences in an effort to collect geoscience information that can assist in the evaluation of a potential shale gas resource. **Figure 1** shows the project area, and **Figure 2** shows the formations being studied.

The project was introduced in Nicolas (2008), and Bamburak (2008) provided the historical background of the gas shows, which dates back to over century (**Figure 3**). Geochemistry, mineralogy and gas and water chemistry data was collected; many of these results are discussed in Fedikow et al. (2009), Nicolas and Bamburak (2009), Nicolas and Grasby (2009), and Nicolas et al. (2010).

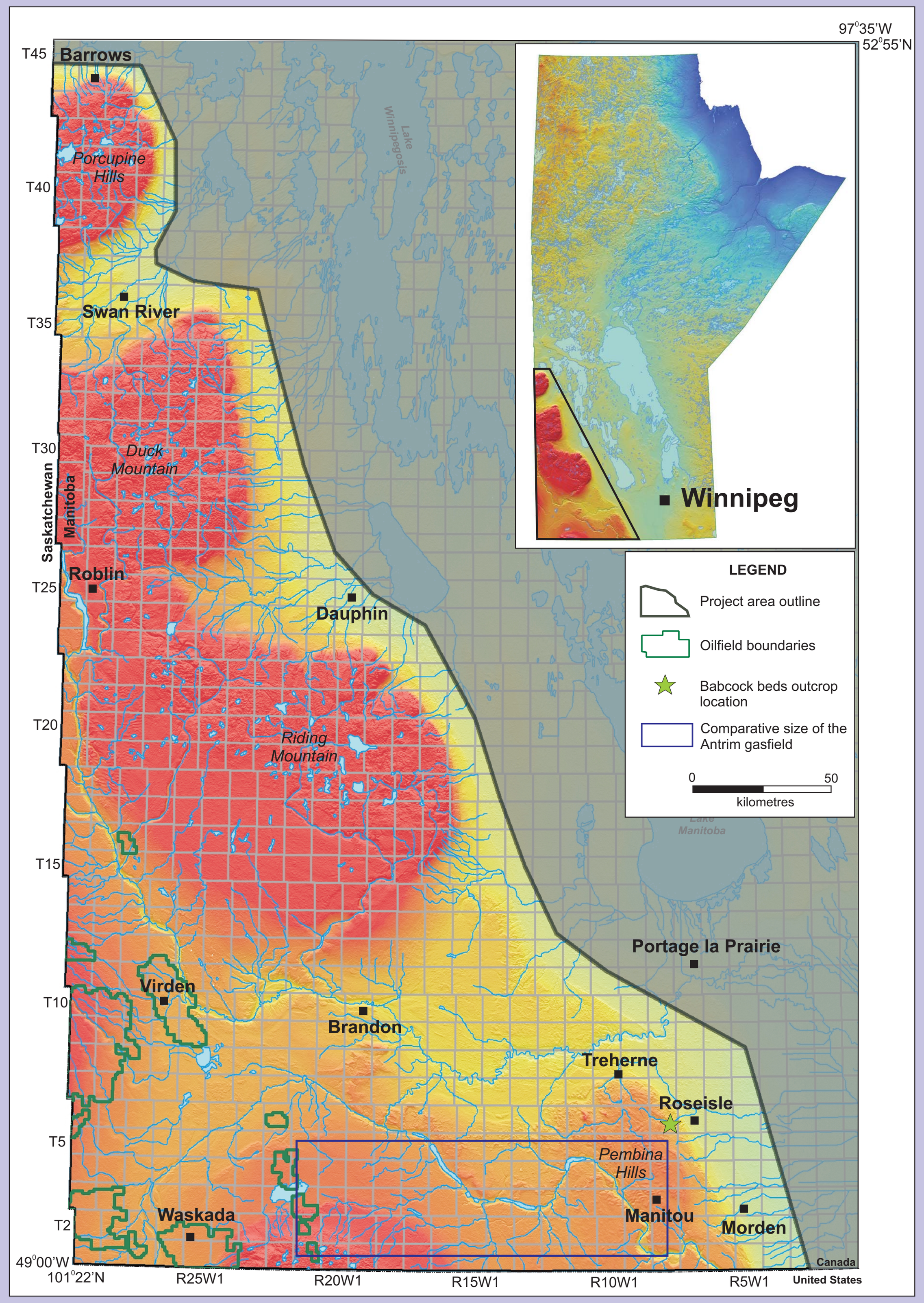

Figure 1: Digital elevation model showing the study area of the Shallow Unconventional Shale Gas Project, showing the Babcock beds outcrop location and the comparative size of the Antrim gasfield (located in the Michigan Basin).

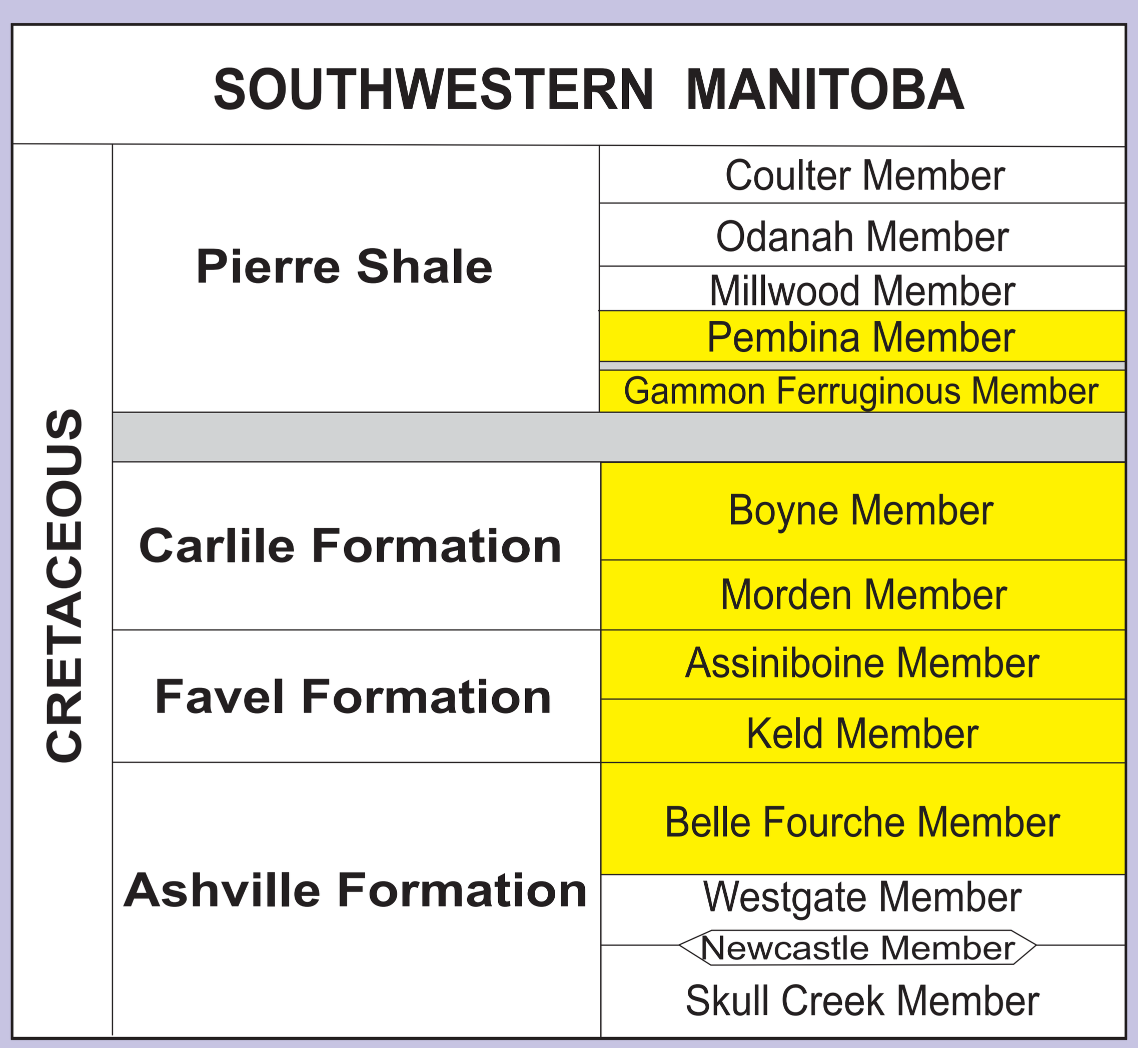

Figure 2: Cretaceous stratigraphic column of southwestern Manitoba showing the target formations for this study; highlighted members have documented gas shows.

Assessing Manitoba's shale gas potential

Assessment of a potential shale gas play in southwestern Manitoba requires basic information including, but not limited to, the presence of organic matter (total organic carbon (TOC) content), maturity of the organic matter (thermal maturity), type of gas in the reservoir, and permeability of the reservoir (Rokosh et al., 2009). In an attempt to address some of this basic information, during the course of this project, information on organic matter, both TOC and maturity, and gas chemistry have been collected and analyzed (Nicolas and Bamburak, 2009; Nicolas and Grasby, 2009). The data collected so far indicates that southwestern Manitoba has an aerially extensive, thick sequence of fine-grained, organic-rich shale. Gas chemistry indicates a 100% biogenic methane resource in the Pembina Hills region, with good probability to extend west and northward along and into the Manitoba Escarpment. Evidence for shale gas potential further north along the escarpment are from reported gas shows in two water wells that were drilled and immediately abandoned due to gas; these wells are located north of the town of Swan River, just off the southeast slope of the Porcupine Hills, in Twp. 39, Rge. 26 to 27, W 1st Mer.

A key discovery, is the presence of siltstone beds, which are informally referred to as the Babcock beds (Nicolas and Bamburak, 2009), in the Boyne Member within the Carlile Formation, located near the community of Roseisle (**Figure 1**). **Figure 4** shows a photograph of these beds with some organic chemistry and mineralogy results, a close up of one of the siltstone beds, and a scanning electron microscopy image of the siltstone showing the micro-scale pores within the siltstone. These siltstone beds are porous (up to 12% porosity; Nicolas et al. 2010), have a high organic content (up to 10.55 wt.% TOC; Nicolas and Bamburak, 2009), and produce biogenic gas near the community of Notre Dame de Lourdes, as measured in an old water well (**Figure 3**).

Extended into the subsurface, these beds represent a potential shale gas reservoir. Preliminary geophysical log correlations show the lateral continuity of these beds go west up to the provincial border, pinching in and out. There have been up to three sandy/silty intervals identified within the Boyne Member in the subsurface to date. Pason gas readings recorded during the drilling of modern oil wells, consistently have high gas readings within the Boyne Member. Other intervals with high Pason gas readings,and good shale gas potential, include the Pembina Member, Gammon Ferruginous Member, Carlile Formation, Favel Formation, and the Belle Fourche Member (**Figure 2**).

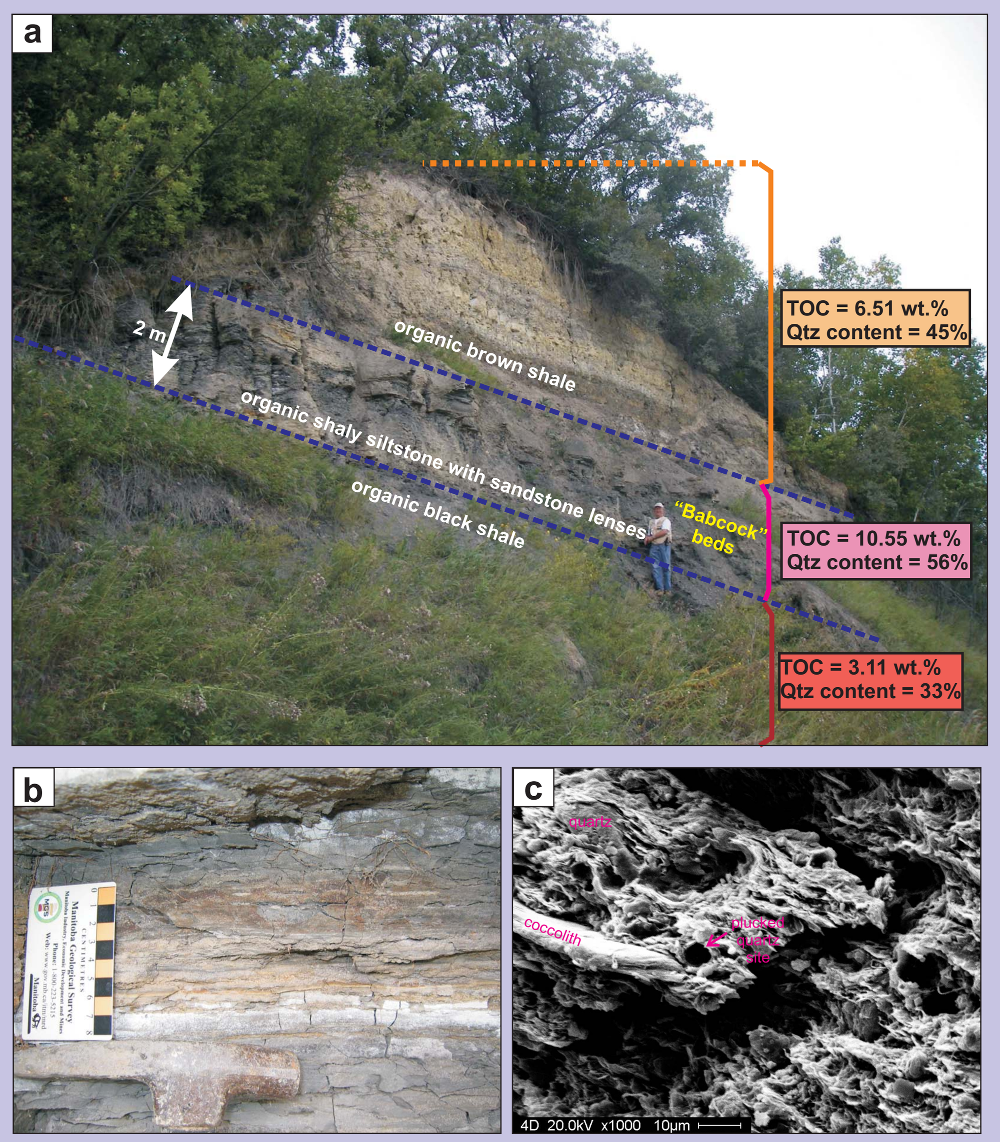

Figure 4: Summer 2008 field work photos showing outcrop of the lower Boyne Member beds, an excellent source and potential reservoir rock: **(a)** outcrop of the lower to middle section of the Boyne Member in Snow Valley, near the community of Roseisle, with organic shaly siltstone and sandstone beds ("Babcock" beds) more resistant to weathering than the overlying and underlying shale, well developed, large-scale vertical jointing is also visible; 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; **(c)** SEM image of the shaly siltstone in (b) showing horizontal porosity, parallel to bedding, as controlled by the fissile nature of the bed, black spherical voids represent areas where quartz grains fell out during sampling preparation, 1000x magnification.

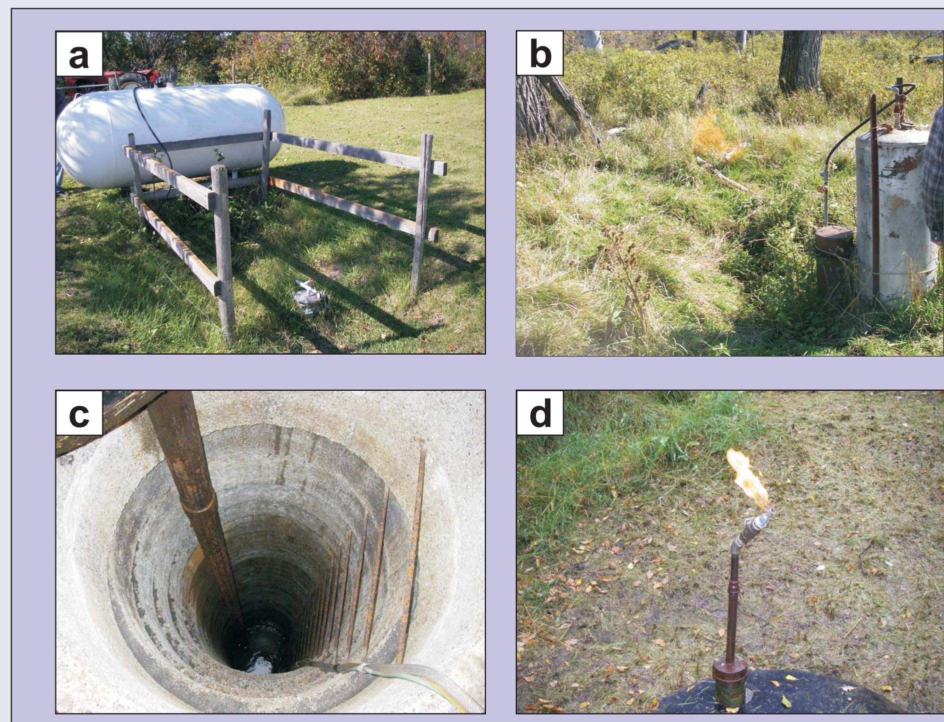

Figure 3: Gas shows in the Pembina Hills in southwestern Manitoba: **(a)** gas well head and storage tank near Manitou, Manitoba, well drilled in 1933; **(b)** flaring of gas well head with storage tank near Manitou, Manitoba, well drilled in 1907;**(c)** gas bubbles in water well near Notre Dame de Lourdes, Manitoba, well drilled in 1936; **(d)** flaring of water/gas well near Notre Dame de Lourdes, Manitoba, well drilled in 1936.

Analogues

There are many shale gas basins in North America promising large resources. Some of the most popular include the Barnett Shale in the Fort Worth Basin (Texas, USA), Ohio Shale and Marcellus Formation in the Appalachian Basin (New York and Pennsylvania, USA), the Antrim Shale in the Michigan Basin (Michigan, USA), the Lewis Shale in the San Juan Basin (New Mexico and Colorado, USA), the Muskwa Formation in the Horn River Basin (Alberta and British Columbia, Canada), and the Montney and Milk River formations and Colorado Group shale sequence in the Western Canadian Sedimentary Basin (Alberta and Saskatchewan, Canada). **Figure 5** shows the major shale gas basins and formations of select shale gas plays in North America. The shale gas plays in all these basins are unique, each requiring specific exploration and development techniques to achieve economic production of gas. Of all these basins, the Antrim Shale in the Michigan Basin represents the closest analogue to the potential shale gas play that exists in southwestern Manitoba.

Boyne Sand near Kamsack, Saskatchewan

In the Kamsack area of southeastern Saskatchewan, commercial production of gas from the Boyne Member of the Carlile Formation was achieved in the early to mid 1900s. The gas was produced from a shallow reservoir called the Boyne Sand Pool (Simpson, 1970), and is stratigraphically equivalent to Babcock beds and other sand/silt beds in the Boyne Member in southwestern Manitoba (Nicolas and Bamburak, 2009). Production values collected from this pool can serve as a potential analogue to the gas possibilities of the Boyne Member in Manitoba, and are included for comparison with the Antrim Shale and Manitoba prospects in **Table 1**.

Antrim Shale

The Antrim Shale is an organic, gas-bearing Devonian shale and siltstone sequence located in the Michigan Basin. The Antrim gasfield is outlined by the blue box in **Figure 1** and is displayed to show its relative size compared to the Cretaceous shale occurrences in Manitoba. The Antrim Shale gas pools are located along the northern rim of the basin, where the shale sequences subcrop at shallow depths below a thin glacial drift cover (Curtis, 2002; Rokosh et al., 2009). Early gas production in these pools was from unstimulated, vertical wells. The most productive wells occurred along natural fractures (Curtis, 2002). Influx of fresh meteoric water and methane-producing bacteria into the formation through outcrops and natural fractures has produced a gas that is dominantly biogenically derived; a minor thermogenic component is present and is likely derived from gas seepage from deeper formations (Curtis, 2002; Rokosh et al., 2009). The thick shale sequence of the Antrim Shale has high TOC values and is thermally immature. With the exception of the age of the rocks, the details of the Antrim Shale mentioned above could easily be substituted for what is known about the Cretaceous shale sequence in southwestern Manitoba; **Table 1** shows the comparison of the Antrim Shale gas play properties with two potential plays in Manitoba. The Antrim Shale has had gas shows for two centuries, but has had commercial production since 1980 with over 9000 wells drilled.

Table 1: Properties of shale gas plays and prospects (modified from Faraj et al. 2004; Rokosh et al, 2009).

Characteristic	Antrium Shale	Boyne Sand Pool	Favel Formation	Boyne Mb, Carlile Fm
Reference	Faraj et al., 2004; Rokosh et al., 2009	Simpson, 1970	Nicolas and Bamburak, 2009; Nicolas and Grasby 2009	Nicolas and Bamburak, 2009; Nicolas and Grasby 2009
Basin	Michigan	WCSB[1]	WCSB[1]	WCSB[1]
Location	Michigan, USA	Kamsack, SK	Manitou, MB	Notre Dame De Lourdes, MB
Age	Devonian	Cretaceous	Cretaceous	Cretaceous
Depth (m)	183 - 610	~ 60	~ 180	66 - 74
Thermal Maturity	immature (R_o=0.4-1.6)	immature	Immature (T_{max}=403-431°C)	Immature (T_{max}=408-427°C)
TOC (wt. %)	0.5-20	NA	0.29-11.17	0.74-10.55
Gas Production (mcf/day per well)	40 - 500	151	NA	NA
Water Production (barrels per day)	20 - 100	NA	NA	NA
Well Spacing (hectares)	16-64	NA	NA	NA
Recovery Factor	20 - 60	NA	NA	NA
Gas-in-place (Bcf/section)	8 - 16	NA	NA	NA
Resources (Tcf)	12 - 20	NA	NA	NA
Total gas production	35-76 Tcf[2]	168 MMcf[3]	NA	NA

[1] Western Canadian Sedimentary Basin
[2] as of 2005 (Canadian Society for Unconventional Gas, 2010)
[3] as of c.1950 (Saskatchewan Ministry of Energy and Resources and National Energy Board, 2008)

Figure 5: Shale gas basins in North America (purple) with formation names of select major shale gas plays. (modified from Spencer et al., 2010; compiled from GSC OF5384 [data provided from T. Hamblin and E. Macey, GSC Calgary], and EIA [http://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/maps/maps.htm]).

Exploration and production methods

Fedikow et al. (2009) conducted a soil geochemistry survey around one of the historical gas wells near the village of Manitou in Twp. 2, Rge. 9, W 1st Mer., and the results suggest seepage gas sites exist, and that soil surveys may be one way to find them. Given the natural fracturing present in the shale outcrops along the Manitoba Escarpment, and following the example of the Antrim Shale, these seepage sites likely occur along natural fracture systems, providing a natural permeability to the shale gas units and a conduit for the gas to concentrate and vent to the surface. During the two field seasons, regular fracture patterns were observed and orientations measured in some outcrops along the Manitoba Escarpment. If the gas seepage is related to the natural fracture systems, structural mapping of these fractures in both the horizontal and vertical directions could be used as an early exploration tool to find shale gas, particularly where dominant fracture sets and intersections of orthogonal fractures may provide sweet pockets of gas (Curtis, 2002). An example of a fracture pattern study for shallow gas applications is described in Shurr (1998); such studies have also been done for the Antrim Shale (Goodman and Manness, 2008).

This type of shale gas has been known to be extractable from simple, unstimulated vertical wells, as was the case in the wells drilled prior to 1950 with cable tool rigs in the Pembina Hills, near the village of Manitou (**Figure 3**), but stimulation increases gas recovery significantly. Drilling, stimulation and completion techniques in shale gas plays have improved significantly over the years, particularly in the last decade. Horizontal wells with multistage fracs are commonly used in many shale gas plays with advantages and disadvantages, but the Antrim Shale gas play responds best to stimulated vertical wells. Several gas-bearing horizontal beds can be accessed in a single stimulated vertical well, and the shallow depths make vertical drilling less expensive and thus more economic.

Discussion

Relative to other shale gas reservoirs, the geochemistry, mineralogy and porosity of the Babcock beds are comparable to the Barnett Shale in Texas and the Buckinghorse Formation in northeastern British Columbia, the Antrim Shale in Michigan, the Duvernay and Muskwa formations in Alberta and the Lewis Shale in the San Juan Basin in New Mexico and Colorado. The characteristics of the Babcock beds are also comparable to sequences that host shale gas plays in southwestern Saskatchewan and Montana, such as the Greenhorn Formation, Carlile/Bowdoin Sandstone and Niobrara/Medicine Hat Sandstone (Koladich and Wilson, 2002).

The Antrim Shale is the best analogue for the Cretaceous shale gas prospect in southwestern Manitoba. The two plays have several characteristics in common, including natural fracturing, a history of fresh water recharge, shallow depths, high total organic carbon (TOC) values, thermal immaturity, thick shale sequences and biogenic gas generation.

Economic considerations

The economic potential for shale gas production from the Cretaceous shale sequences in southwestern Manitoba is considerable. As its closest analogue, the success of the Devonian Antrim Shale in the Michigan basin is proof that such a shale gas play can be profitable and sustainable. To date, the Shallow Unconventional Shale Gas Project has provided some of the basic information needed to evaluate Manitoba's shale gas prospect. Initial results are more than encouraging and have already attracted the energy industry's attention, finally putting Manitoba on the 'potential shale gas play' map.

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References

Bamburak, J.D. 2008: Geochemistry of Upper Cretaceous shale in southwestern Manitoba (NTS 63F, G, H4): potential reservoir rocks for shallow unconventional shale gas; in Report of Activities 2008, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 180–184.

Canadian Society for Unconventional Gas 2010: Shale gas; Canadian Society for Unconventional Gas, URL <http://www.csug.ca/index.php?option=com_content&task=view&id=60&Itemid=66#shale> [October 2010].

Curtis, J.B. 2002: Fractured shale-gas systems; AAPG Bulletin, v. 86, no. 11, p. 1921–1938.

Faraj, B., Williams, H., Addison, G. and McKinstry, B. 2004: Gas potential of selected shale formations in the Western Canadian Sedimentary Basin; GasTIPS, v. 10, no. 1, p. 21–25.

Fedikow, M.A.F., Bezys, R.K., Nicolas, M.P.B. and Prince, P. 2009: Preliminary results of soil geochemistry surveys in support of shallow gas exploration, Manitou area, Manitoba (NTS 62G2); in Report of Activities 2009, Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, p. 193–206.

Goodman, W.R. and Manness, T.R. 2008: Michigan's Antrim shale play; a two-decade template for successful Devonian gas shale development (abstract); 2008 American Association of Petroleum Geologists Annual Convention and Exhibition, San Antonio, Texas, abstract volume.

Koladich, A. M. and Wilson, M. 2002: The Upper Cretaceous Medicine Hat and Milk River formations in southeastern Alberta: stratigraphy, sedimentology and ichnology of a shallow gas interval, 2002 CSPG Annual Convention: Calgary, AB, http://www.cspg.org/conventions/abstracts/2002abstracts/022S0107.pdf [access date: October 21, 2010]

Nicolas, M.P.B. 2008: Summary report on petroleum and stratigraphic investigations, southwestern Manitoba; in Report of Activities 2008, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 171–179.

Nicolas, M.P.B. and Bamburak, J.D. 2009: Geochemistry and mineralogy of Cretaceous shale, Manitoba (parts of NTS 62C, F, G, H, J, K, N): preliminary results; in Report of Activities 2009, Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, p. 165–174.

Nicolas, M.P.B., Edmonds, S.T., Chow, N., and Bamburak, J.D. 2010: Shallow unconventional Cretaceous shale gas in southwestern Manitoba (parts of NTS 62C, F, G, H, J, K, N): an update; in Report of Activities 2010, Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, p. – .

Nicolas, M.P.B. and Grasby, S.E. 2009: Water and gas chemistry of Cretaceous shale aquifers and gas reservoirs of the Pembina Hills area, Manitoba (parts of NTS 62G); in Report of Activities 2009, Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, p. 175–182.

Rokosh, C.D., Pawlowicz, J.G., Berhane, H., Anderson, S.D.A. and Beaton, A.P. 2009: What is shale gas? An introduction to shale-gas geology in Alberta; Energy Resources Conservation Board, ERCB/AGS Open File Report 2008-08, 26 p.

Saskatchewan Ministry of Energy and Resources and National Energy Board 2008: Saskatchewan's ultimate potential for conventional natural gas; Saskatchewan Ministry of Energy and Resources and National Energy Board, Miscellaneous Report 2008-8, 30 p.

Shurr, G.W. 1998: Shallow gas play around the margins of the Williston Basin; in Eighth International Williston Basin Symposium, J.E. Christopher, C.F. Gilboy, D.F. Paterson and S.L. Bend (eds.), Saskatchewan Geological Society, Special Publication 13, p. 129–139.

Simpson, F. 1970: Low depth Saskatchewan prospect; Oilweek, March 30, 1970.

Spencer, R.J., Pedersen, P.K., Clarkson, C.R. and Aguilera, R. 2010: Shale gas series: Part 1 – Introduction; Reservoir, no. 8, p. 47–51.

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M.P.B. Nicolas and J.B. Bamburak
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