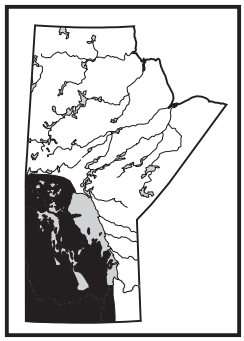
GS-17 Geochemistry of Upper Cretaceous shale in southwestern Manitoba (NTS 63F, G, H4): potential reservoir rocks for shallow unconventional shale gas

by J.D. Bamburak



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Summary

Shallow unconventional shale gas is present in Upper Cretaceous shale sequences in southwestern Manitoba. The chemostratigraphic signature of the shale sequences may assist in the determination of the shale's mineralogy, which may lead to the discovery of the provenance of the gas. The results of new geochemical analyses will be added to the historical geochemical results currently stored in the black shale database of the Manitoba Geological Survey (MGS).

The new analytical results may also be useful in the determination of potential Cretaceous horizons containing sedimentary exhalative (SEDEX) base- or precious-metal occurrences in southwestern Manitoba.

Introduction

Shallow gas has been found in water and petroleum exploration wells in southwestern Manitoba for almost one hundred years. The origin of this gas is unknown and requires further study, as proposed by Nicolas (GS-16, this volume). These studies will include sampling and mineralogical analysis of Manitoba's Upper Cretaceous shale sequences by determination of their geochemical signatures. Historical major-element and more recent trace-element and whole-rock data from these formations have been published in various government and industry reports for well over one hundred years. This data and new trace-element and whole-rock analytical results from samples collected during Phase I (shown in Figure GS-16-4, this volume) will be added to the chemostratigraphic database of the MGS (Fedikow et al., 1997, 1998; Garrett et al., 2001).

Shallow gas discoveries in Manitoba

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 11 gas well localities, including those of Wallace and Greer. Many of these locations were also listed, to December 31, 2004, in a compilation of "Mesozoic drill stem tests and oil & gas shows" (Manitoba Industry, Economic Development and Mines, 2005a). The compilation of 18 gas shows was produced by the Petroleum Branch of Manitoba, Industry, Economic Development and Mines.

Waskada–Sourisford district

Since Wallace and Greer's report, the following gas shows have been documented in the Waskada–Sourisford district:

- Sixteen wells drilled in Twp. 3 to 8 and Rge. 28 to 29, W 1st Mer. reported gas shows within Cretaceous shale ranging from the Millwood Member of the Carlile Formation down to the Ashville Formation (Figure GS-17-1). The Favel Formation is mentioned as the source for many of these shows (Manitoba Industry, Economic Development and Mines, 2005a).
- A strong gas smell was reported from cut core from the Favel Formation (Figure GS-17-1) from a hole drilled in L.S. 11, Sec. 29, Twp. 1, Rge. 25, W 1st Mer. (abbreviated 11-29-1-25-W1). Gas pressures of 97 kPa were also measured in two holes in Pierre shale in NE-5-2-25-W1 and 8-2-25-W1. A pressure of 117 kPa was measured in Pierre shale in a hole drilled in SW-10-2-27-W1.
- A petroleum well being drilled near Pierson was damaged in a gas blowout on August 1, 2005. The well was Big Sky #5 in the Tundra Pierson Province, 16-36-3-29-W1. The gas was trapped in gravel beneath a layer of cemented Quaternary till (Figure GS-17-1). The well had been drilled down 139 m (at the time of blowout) within a shale bed that is believed to have contained the gas that caused the blowout.

Treherne area

- A local natural gas source is situated along the Manitoba Escarpment, 6 km north-northeast of Notre Dame de Lourdes, within a water well (located on the farm of Normand and Guy Bosc in 1-30-7-8-W1). The well, drilled around 1930, produces a weak petroleum-smelling gas with pressure of 221 kPa that burns for at least 0.5 hours when ignited. After ignition, the gas pressure drops to 21 kPa, but the well recharges in 12 hours when the valve is closed. A short video of the well being ignited can be viewed on the Internet (Manitoba Industry, Economic Development and Mines, 2005b). Carlile (formerly Niobrara) Formation (Figure GS-17-1) bedrock is exposed at two locations: a short distance to the southeast and to the southwest of the well. The exposures are at about the same elevation as the top of the well. The 52 m deep well likely penetrated the Favel Formation (Figure GS-17-1), which is an oil shale. According to

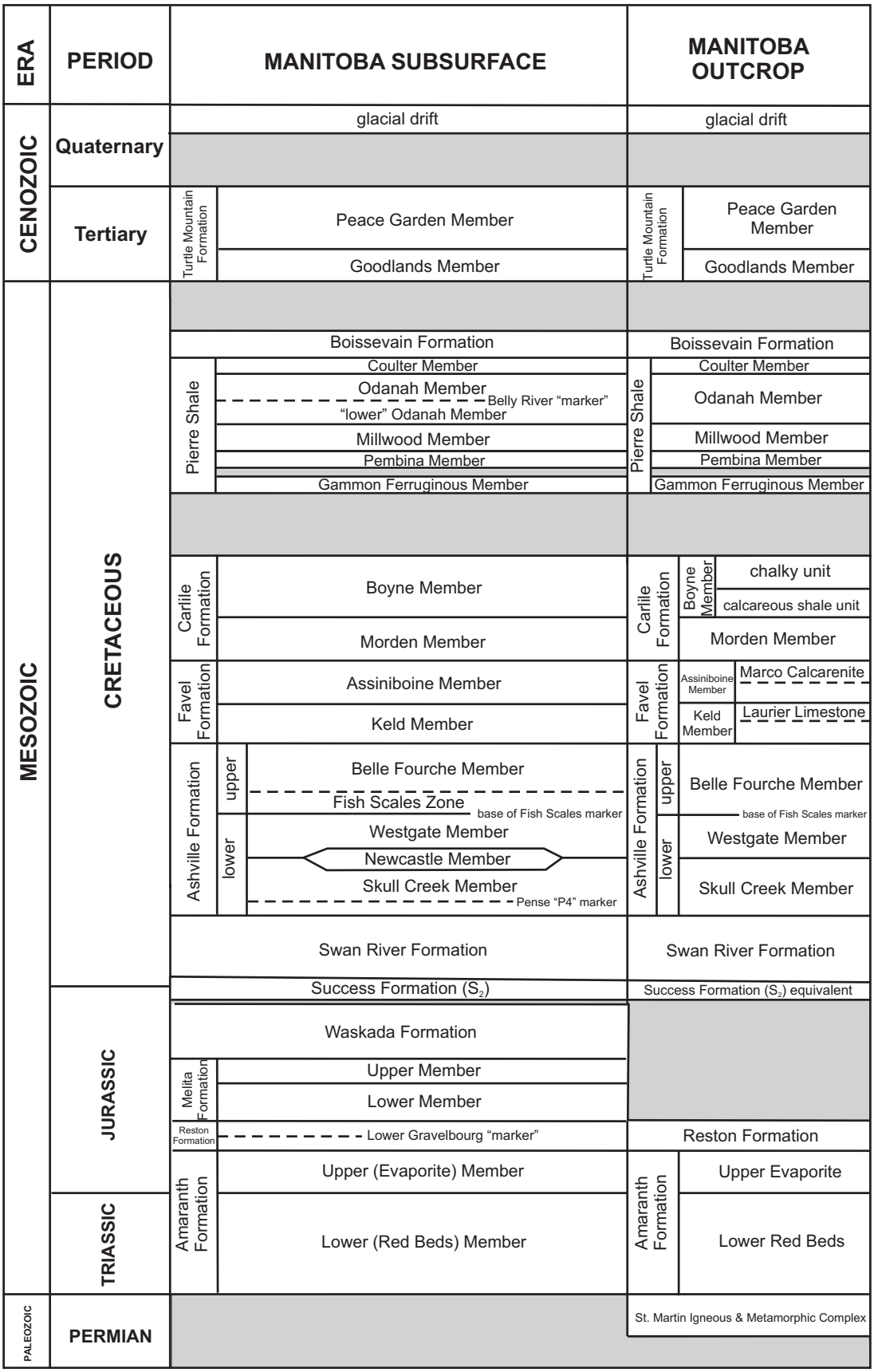

Figure GS-17-1: *Mesozoic and Cenozoic stratigraphy of southwestern Manitoba within the subsurface and outcrop belt (M. Nicolas, work in progress, 2008).*

Normand Bosc, poor-quality drinking water has been encountered in all wells drilled in Sec. 30.

- Two other gas sources, identified in SW-21-7-8-W1 and NE-28-7-10-W1, were also used in the past for household consumption. Gas was also found within a water well in 11-5-7-W1. The Favel Formation (Figure GS-17-1) is believed to be the source of all these gas occurrences.

Manitou area

- Two capped gas wells, with pressure of about 276 kPa, are situated in the south half of 23-2-9-W1, about 13 km south of Manitou. One of the wells has produced shallow shale gas since it was drilled into the Boyne Member (Figure GS-17-1) in 1907. The other well was drilled around 1933. Both wells were ignited by a local landowner, Percy Lea, during a water and gas well sampling visit in September 2008. The 1933 well feeds a small storage tank and a typical gas barbecue, which is used to cook food on special occasions. Another gas occurrence is present, a short distance to the west, in a domestic farm water well in 2-22-2-9-W1 in Morden shale.
- Gas shows were also reported in the 1930s from Cretaceous shale in petroleum test wells drilled in NE-13-2-10-W1 and 8-26-2-9-W1.

Other areas

- A petroleum test well near Miniota caught fire during formation testing over 20 years ago and was abandoned after the fire was extinguished, according to a long-time local resident. The well is believed to be Champlin Birdtail Creek 1-29-14-26-W1, which was drilled in 1968 to a depth of 629.41 m. The Favel Formation (Figure GS-17-1) was penetrated at a depth of 253.7 m. Another test well in NW-23-10-26-W1 had a gas pressure of 172 kPa in Pierre shale.
- An initial gas pressure of 331 kPa, followed in a few hours by a drop to 241 kPa, was reported from Pierre shale (Figure GS-17-1) in a well drilled near Hartney in NW-4-6-22-W1.

Geochemical sampling and analyses of Cretaceous shale

Previous work

The earliest geochemical analyses of Cretaceous shale in southwestern Manitoba were reported in the literature by Wells (1905a, b, c). These whole-rock analyses were followed by a study by Turner (1917), who analyzed Pembina Member (Figure GS-17-1) samples that had been collected by MacLean (1915a, b; 1916). Goudge (1944) reviewed the earlier studies, as well as providing new whole-rock analyses.

Ross and Buchanan (1962) reported on the whole-rock chemical analyses of nine air-dried composite Cretaceous shale samples supplied by the Manitoba Geological Survey from four localities in Morden-Miami and Pembina Valley areas. The results of Ross and Buchanan were also documented by Bannatyne (1963).

Bannatyne (1970) compiled, by formation and member, many of the previous whole-rock geochemistry results, described above, in his comprehensive report on *The Clays and Shales of Manitoba*. In 1979, Canada Cement Lafarge Ltd. completed whole-rock chemical analyses of two core holes drilled by the MGS in 1977 (M-8-77 and M-12-77) in the Morden-Miami area. In the fall of 1986, Canada Cement followed up this earlier work by drilling six additional holes near Babcock, 40 km northwest of Morden, on former Quarry Exploration Permits QP-61 to 64; and had whole-rock analyses done on the core.

Guillet (1989) reported on the whole-rock geochemistry of 20 clay samples from the Morden-Miami bentonite deposit, formerly operated by Pembina Mountain Clays Ltd. Chemical analyses on samples, oven dried at 80°C and crushed and ground to <74 μm, were done by x-ray fluorescence, after fusion with lithium metaborate. Trace-element analyses for Cr, Rb, Sr, Y, Zr, Nb and Ba were also done. It is believed that this was the first trace-element analytical work on Cretaceous shale to be reported in the literature.

In 1995, a black shale geochemical database for metallogenic studies in Manitoba was initiated (Fedikow et al., 1997) under a joint MGS–Geological Survey of Canada (GSC) study. Representative samples of drillcore, outcrop chips and archived percussion well chips were submitted for multi-element analysis. Analytical methods chosen were instrumental neutron activation analysis (INAA) and inductively coupled plasma–atomic emission spectrometry (ICP-AES). The results of these studies were released by Fedikow et al. (1998), briefly described in their stratigraphic setting by Garrett et al. (2001) and entered into the black shale geochemical database.

Present work

During the early summer of 2008, a literature search was carried out to identify, classify and summarize, by formation, member and/or bed, all of the available whole-rock analyses of Cretaceous shale in published and unpublished documents. The results of the search, shown in Table GS-17-1, revealed that 110 samples were analyzed at 10 outcrop localities, and 48 samples were compiled from eight mining company and stratigraphic core holes drilled in southwestern Manitoba. This search also indicated gaps in the whole-rock geochemical knowledge within the stratigraphic package.

A similar review of trace-element distribution by formation, member and/or bed captured mainly from Open File Report OF98-2 by Fedikow et al. (2008) has been initiated. A preliminary listing summarizing the results of

Table GS-17-1: Status of whole-rock and trace-element geochemical analyses, Cretaceous strata, southwestern Manitoba.

	Whole Rock		Trace Element	
Rock Unit	**Number of Samples**	**Sample Type**	**Number of Samples**	**Sample Type**
Outcrop				
Boissevain Formation-sand	0		4	Spot
Boissevain Formation-sandstone concretion	0		1	Spot
Boissevain Formation-kaolinitic shale	1	Spot	0	
Coulter Member	0		0	
Odanah Member	3	Spot	16	Spot
Odanah Member-limestone concretion			1	Spot
Millwood Member	51	Channel over 17.3 m	6	Spot
Pembina Member-black shale	1	Composite	67	Spot and channel
Pembina Member-calcium bentonite	32	Composite		
Gammon Ferruginous Member	0		11	Spot
Boyne Member-chalky unit	2	Spot	38	Spot
Boyne Member-calcareous cement rock	14	2 channels over 2.1 m	0	
Boyne Member-calcareous shale unit	3	Spot	32	Spot
Morden Member	1	Spot	23	Spot
Assiniboine Member-shale	0		13	Spot
Assiniboine Member-Marco calcarenite	2	Spot	5	Spot
Keld Member	0		1	Spot
Ashville Formation	0		0	
Swan River Formation	0		0	
Drillcore				
Boissevain Formation	0		0	
Coulter Member	0		1	Core from 1 hole
Odanah Member	0		0	
Millwood Member	2	Core from 2 holes	0	
Pembina Member	10	Core from 3 holes	0	
Gammon Ferruginous Member	0		0	
Boyne Member-chalky unit	14	Core from 3 holes	11	Core from 1 hole
Boyne Member-calcareous cement rock	2	Core from 1 hole	0	
Boyne Member-calcareous shale unit	11	Core from 4 holes	24	Core from 2 holes
Morden Member	4	Core from 2 holes	10	Core from 1 hole
Favel Formation	5	Core from 1 hole	35	Core from 1 hole
Ashville Formation	0		0	
Swan River Formation	0		0	

81 sample whole-rock and trace-element analyses from four stratigraphic holes of the MGS and GSC drilled in southwestern Manitoba is shown in DRI2008003[1]. Future work will involve the compilation and integration of trace-element distribution by formation, member and/or bed from oil company exploration core and outcrops, also described in Open File Report OF98-2.

Bedrock sampling in the Cretaceous outcrop belt within the Phase I area (shown in Figure GS-16-4, this volume) was done in late August 2008. In addition to the

[4] MGS Data Repository Item DRI2008003, containing the data or other information sources used to compile this report is available online to download free of charge of http://www2.gov.mb.ca/itm-cat/freedownloads.htm, or on request from minesinfo@gov.mb.ca or Mineral Resources Library, Manitoba Science, Technology, Energy and Mines, 360–1395 Ellice Avenue, Winnipeg, MB R3G 3P2, Canada.

analytical methods proposed by Nicolas (GS-16, this volume), the samples will be sent out for INAA and ICP-AES. The results will be used to fill in gaps in the MGS's chemo-stratigraphic database, described above. Water and gas samples were also collected at 14 localities within the Phase I area in September 2008, as described by Nicolas (GS-16, this volume).

Economic considerations

As stated by Nicolas (GS-16, this volume), "Unconventional shallow gas prospects in Manitoba are currently very little understood, but many companies throughout the history of oil and gas exploration in Manitoba have looked at this resource, without much success." The purpose of adding to the geochemical database of trace-element and whole-rock geochemical analyses of Upper Cretaceous formations, members and/or beds is to provide a complete package of information to attract potential investors and companies "to undertake exploration in the new and risky unconventional shallow gas plays in southwestern Manitoba."

An additional benefit of the new shale geochemical analyses will be the completion of the Upper Cretaceous chemostratigraphic package. The complete package may permit the distinction of the relationships between metal content and shale stratigraphy. The relationships may indicate distinct patterns of mineralization that may reveal hidden SEDEX base- or precious-metal occurrences (Garrett et al., 2001).

Acknowledgments

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