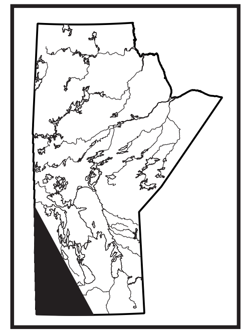
GS-13 Preliminary stratigraphic correlation of subsurface and outcrop sections of the Favel Formation, southwestern Manitoba

by M.P.B. Nicolas, J.D. Bamburak and S. Hosseininejad[1]



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Summary

The Upper Cretaceous Favel Formation[2] in Manitoba is a biogenic, gas-bearing, chalk-speckled, calcareous, sandy to silty mudstone, with abundant thin carbonate beds. This formation is exposed at various locations along the Manitoba escarpment, with the best sections located along the banks of incised river valleys. These outcrop sections were examined in the field, however, it was difficult to position these sections within the overall stratigraphic structure of the formation and its two members. It was decided that a complete core of the Favel Formation recovered from well 3-27-1-25W1 could be used as a reference section. Using a detailed core description, a preliminary correlation of outcrops was attempted to determine their stratigraphic positioning. The selected outcrop sections are located, from south to north, 1) east of the Pembina Hills, and along banks of the 2) Ochre River, 3) Vermilion River, 4) Wilson River, 5) Sclater River, 6) East Favel River, 7) Swan River and 8) Little Woody River.

Stratigraphic positioning of the outcrops is important to better characterize the lateral variability of the Favel Formation in outcrop, as well as to help with long-range subsurface correlations where there is minimal core information available. It was found that the best way to correlate outcrop sections of the Favel Formation was to position the sections lithostratigraphically, based on lithology, relative to the reference subsurface section or other outcrop sections, while ignoring the thickness variability that can occur between outcrop and subsurface sections. The thickness variability of different intervals within the formation and the presence or absence of bentonite beds is due to changes in depositional conditions and synformational erosive events.

Introduction

The Shallow Unconventional Shale Gas (SUSG) Project is a multiyear investigation of the shale gas potential of the Cretaceous shale sequences in southwestern Manitoba. During the course of the project, several aspects of the Cretaceous shale sequences have been studied, both in outcrop and subsurface sections, including detailed stratigraphy, geochemistry and mineralogy (Nicolas and Bamburak, 2009, 2011a–d, 2012a, b; Bamburak and Nicolas, 2010; Bamburak et al., 2012a, b; Hosseininejad et al., 2012). This paper outlines one of the stratigraphic issues that arose while examining and sampling outcrop sections of the Favel Formation along the Manitoba escarpment and along the banks of incised river valleys.

Outcrop information can be used as a proxy to understand subsurface strata, since subsurface core through the Cretaceous section in Manitoba is very rare. One of the challenges faced in this process is that it is often difficult in the field to know exactly where a given outcrop fits with respect to its stratigraphic positioning due to repetitive sedimentary facies, wherein similar lithological units appear, disappear and then reappear millions of years apart. The purpose of this investigation is to place key Favel Formation outcrop sections in their proper stratigraphic position with respect to a subsurface reference core, and discuss some of the similarities and challenges encountered.

The Late Cretaceous Favel Formation consistently has high Pason™ gas readings during drilling, due to in situ, biogenic, gas generation and storage; it is a productive gas unit in equivalent formations in Saskatchewan and Alberta. This supports SUSG Project findings that suggest that the Favel Formation also has the best potential as a shale gas target in southwestern Manitoba (Nicolas and Bamburak, 2011a). Since there is very little core available through the Favel Formation, it is necessary to rely on geophysical wireline logs to help understand the rocks in the subsurface. At surface, outcrop sections of the Favel Formation provide a good large-scale view of the rocks, however, it is often a challenge to place them in a stratigraphic position without an accompanying geophysical signature to help relate them to the subsurface expression of the same units. However, by correlating outcrop and core data simultaneously, it is possible to gain missing critical information from both sets of data.

A detailed description of a 36 m long, continuous, good quality core of the Favel Formation, from a well at L.S. 3, Sec. 27, Twp. 1, Rge. 25, W 1st Mer. (abbreviated 3-27-1-25W1), was used as the subsurface reference

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[2] For the sake of consistency, the Manitoba Geological Survey has opted to make a universal change from capitalized to noncapitalized for the generic part of lithostructural feature names (formal stratigraphic and biostratigraphic nomenclature being the exceptions).

litholog (Figure GS-13-1) to place outcrop locations into their proper stratigraphic position. Hosseininejad et al. (2012) described in detail the subsurface lithofacies, mineralogy and geochemistry of this core. The location of this core is shown on Figure GS-13-2, along with the correlated outcrop sections.

Stratigraphy

The Favel Formation consists of two members, the lower Keld Member and the upper Assiniboine Member. The Belle Fourche Member of the Ashville Formation conformably underlies the Keld Member, while the Morden Member of the Carlile Formation disconformably overlies the Assiniboine Member (Bamburak et al., Figure GS-11-1, this volume). The Favel Formation correlates to the Second White Speckled Shale in Saskatchewan and Alberta.

The Keld Member is a calcareous, sandy, chalk-speckled mudstone with abundant bivalve fossils, including the prominent *Inoceramus* and *Mytiloides* (McNeil

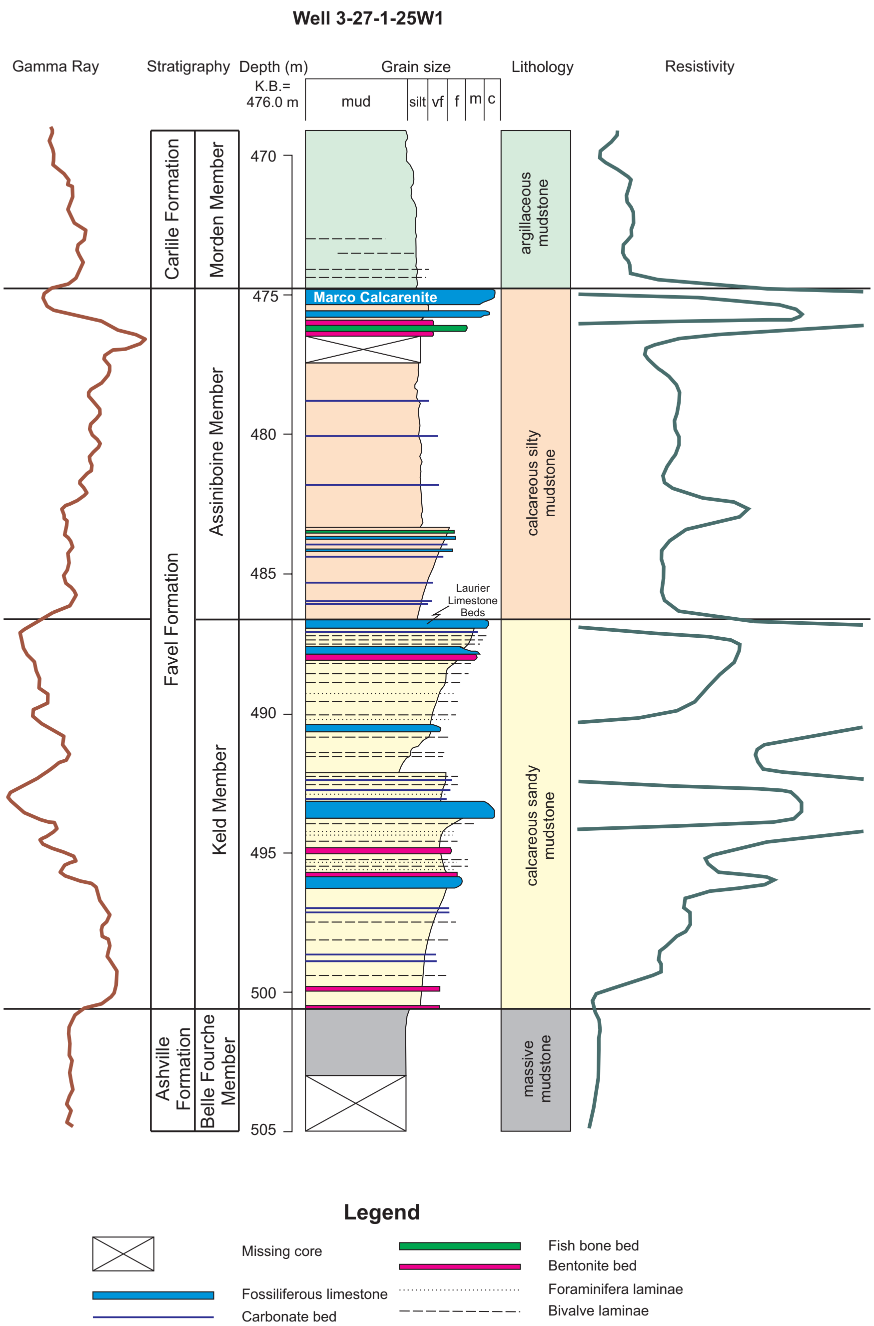

Figure GS-13-1: *Detailed stratigraphy and litholog for the subsurface Favel Formation reference core at L.S. 3, Sec. 27, Twp. 1, Rge. 25, W 1st Mer., southwestern Manitoba. Abbreviations: K.B., kelly bushing; vf, very fine; f, fine; m; medium; c, coarse.*

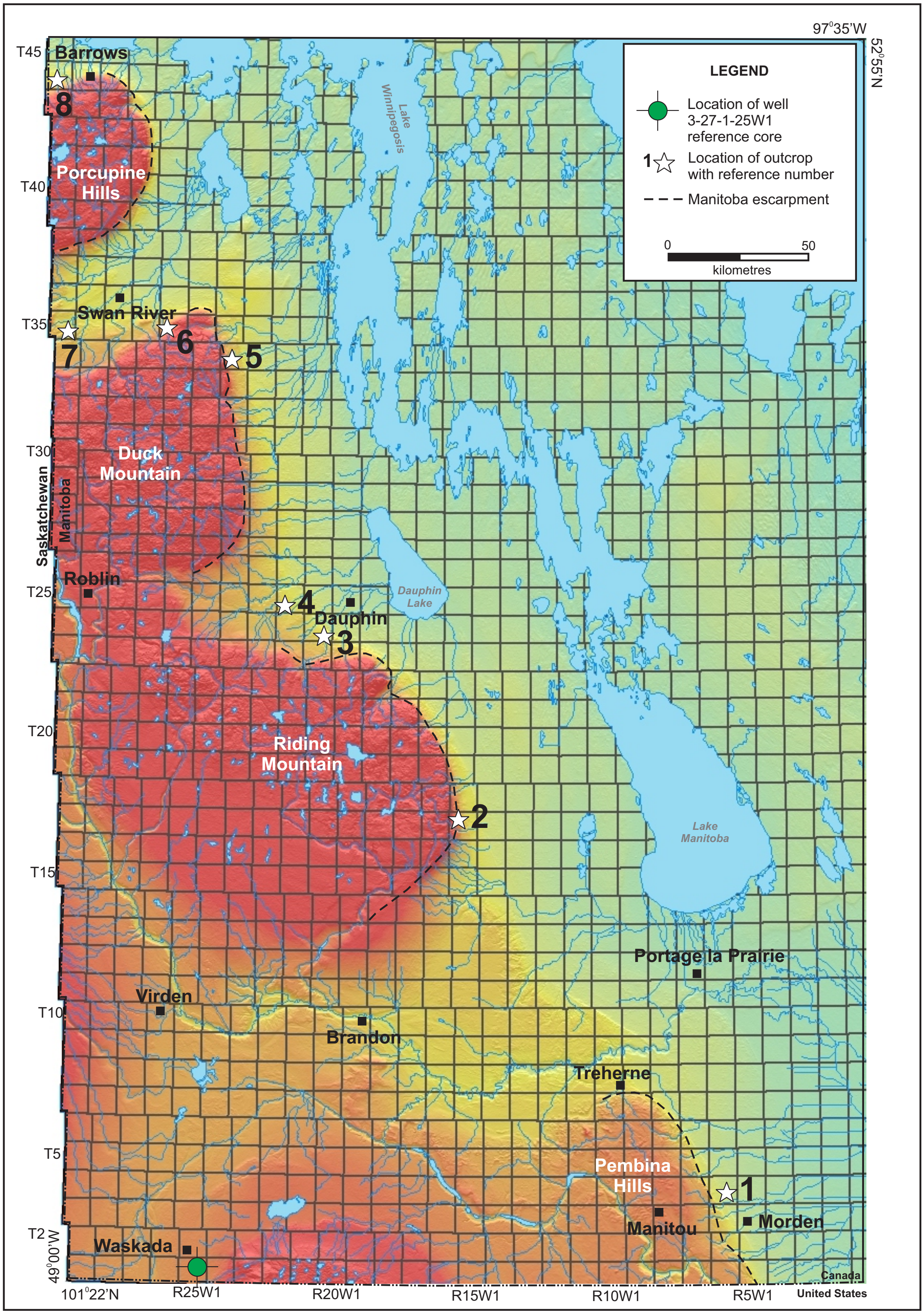

Figure GS-13-2: *Digital elevation model map of southwestern Manitoba (United States Geological Survey, 2002) showing the location of the reference subsurface core (well 3-27-1-25W1) and representative outcrop sections of the Favel Formation (1, east of Pembina Hills; 2, Ochre River; 3, Vermilion River; 4, Wilson River; 5, Sclater River; 6, East Favel River; 7, Swan River; 8, Little Woody River).*

and Caldwell, 1981), foraminifera fossils, intermittent bentonite beds, and common thin argillaceous limestone and calcarenite beds. It is capped by the Laurier Limestone Beds (McNeil and Caldwell, 1981), a prominent regional marker bed of fossiliferous argillaceous limestone. The argillaceous limestone and calcarenite beds are resistive to weathering and form prominent rock shelves in outcrop, while the softer mudstone weathers recessively.

The Assiniboine Member is a calcareous, silty, chalk-speckled mudstone, with a similar biota as the Keld Member, but has fewer fossils within the mudstone and less frequent calcarenite beds, therefore it is less resistant and weathers more recessively than the underlying Keld Member. It is capped by the Marco Calcarenite (McNeil and Caldwell, 1981), a fossiliferous calcarenite, which is also a prominent regional marker that is resistant to weathering. Fish fragments and bivalves are common in the uppermost part of the Assiniboine Member and within the Marco Calcarenite; oyster shells are characteristic of this unit. The Assiniboine Member also has intermittent thin bentonite beds.

The presence of a carbonate bed at the top of each member serves as an excellent marker horizon since each of the carbonate beds has a strong geophysical response on logs compared to the shale-rich units above and below them. Their distinctive log-response signatures make wireline log identification of this formation and its members easy. Figure GS-13-1 shows an example of gamma ray and resistivity logs; an example of subsurface log correlations can be seen in Hosseininejad et al. (2012, Figure GS-14-4).

Outcrop sections

The Favel Formation is exposed at various locations along the Manitoba escarpment, with the thickest exposed sections occurring along the banks of incised river valleys. Figure GS-13-3 shows a group of representative outcrop sections and their stratigraphic positioning relative to the subsurface reference section at well 3-27-1-25W1. The location of each section is shown on Figure GS-13-2. The numbered list below corresponds to the outcrop sections on Figure GS-13-3, and provides details on the locations of these outcrops; all UTM co-ordinates are in NAD 83, Zone 14.

1) East of Pembina Hills: this section is located in 1-14-4-6W1 at UTM 560796E, 5460673N (NTS 62G8); this site was also the site of stratigraphic test corehole M-12-77 drilled by the Manitoba Geological Survey in 1977 (McCabe, 1977).
2) Ochre River: this section is a composite section taken from two key outcrops along the river in the northwest corner of 17-15W1. One is an upstream outcrop at UTM 442848E, 5642132N, and the other is a downstream outcrop located at Skane's crossing at UTM 442738E, 5642331N (NTS 62J13).
3) Vermilion River: this section consists of a composite of two outcrop sections described in McNeil and Caldwell (1981), outcrop sections 80 and 81. The former is located in 5-35-23-20W1 and the latter in 8-2-24-20W1 (NTS 62N1).
4) Wilson River: the upstream section comes from the south bank of the river in 14-10-25-21W1, UTM 406832E, 5667970N (NTS 62N1). The downstream section comes from McNeil and Caldwell's (1981) outcrop section 65 in 9-15-25-21W1 (NTS 62N1).
5) Sclater River: this is a composite section taken from McNeil and Caldwell's (1981) outcrop section 64 in 14-15-34-23W1 (NTS 62N15) and from the authors' field observations at several outcrops centred around UTM 386980E, 5754230N in 13-15-34-23W1 (NTS 62N15).
6) East Favel River: this section is a composite from outcrops located along the river banks, centred on UTM 360817E, 5766094N in 3-30-35-25W1 (NTS 63C7).
7) Swan River: this section is from a river bank outcrop at UTM 328973E, 5761906N in 16-5-35-29W1 (NTS 62N14).
8) Little Woody River: this section is from outcrop section 42 in McNeil and Caldwell (1981) in 11-14-44-29W1 (NTS 63C13).

The stratigraphic sections in Figure GS-13-3 have been depicted at approximately the same scale and the relative thickness of the sections are equivalent to the vertical scale of the subsurface log (where the base of each outcrop section is at river water level). Due to the variability in outcrop descriptions from different authors, not all details were recorded equally, which resulted in an oversimplified section in some instances.

Discussion

The placement of the outcrop sections relative to the subsurface reference section in Figure GS-13-3 is a preliminary attempt to correlate and place the outcrops into their proper stratigraphic position. Some outcrops show markedly different bedding patterns than others, whereas some show striking similarities to the subsurface section or to another outcrop. For example, the Ochre River section (2) correlates exceptionally well with the subsurface core of well 3-27-1-25W1. The capping calcarenite beds in most outcrop sections correlate well, as was expected, but they can vary in thickness. The Ashville Formation–Favel Formation contact correlates well with the abundant occurrence of bentonite beds at this stratigraphic level. The bentonite beds in outcrop in the Assiniboine Member are difficult to correlate to the subsurface section, which shows only two beds near the top of the member whereas outcrop sections record several thin beds throughout. The Keld Member sections show very good correlation overall, with the middle calcarenite bed (marked as a fossiliferous limestone in Figure GS-13-3) having a prominent and regional distribution. However, there is a significant

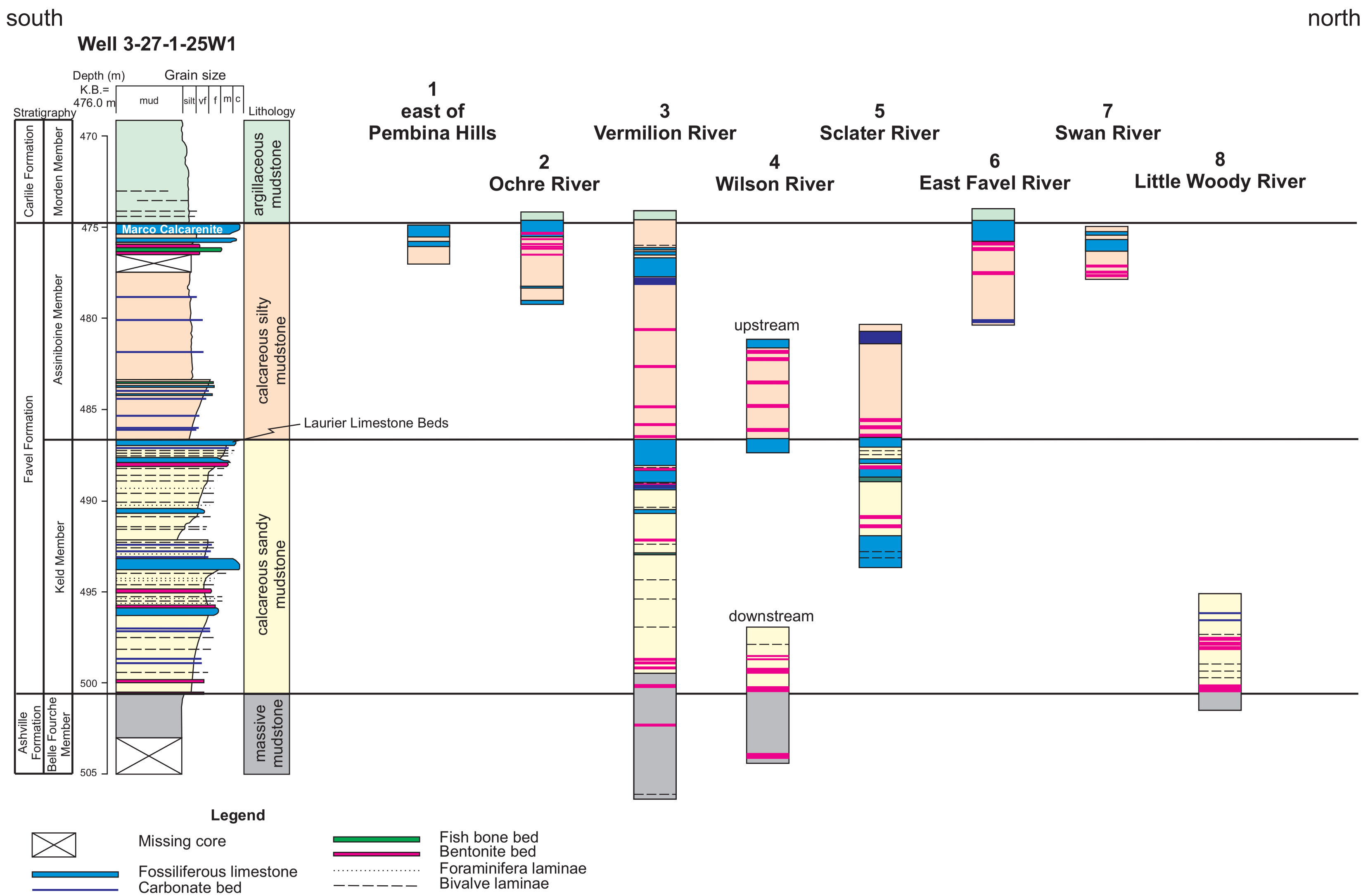

Figure GS-13-3: *Stratigraphic position of composite outcrop sections in the Favel Formation with respect to the subsurface reference log at well 3-27-1-25W1, southwestern Manitoba. Vertical scales of outcrop sections are approximate. Reference for sections: 1, 2, 4 (upstream), 6 and 7, from field observations by the authors; 3, composite of outcrop sections 80 and 81 in McNeil and Caldwell (1981); 4 (downstream), from outcrop section 65 in McNeil and Caldwell (1981); 5, composite of outcrop section 64 in McNeil and Caldwell (1981) and authors' field observations; 8, from outcrop section 42 in McNeil and Caldwell (1981). Abbreviations: K.B., kelly bushing; vf, very fine; f, fine; m; medium; c, coarse.*

isopach thickness variation in the limestone bed located midsection, it is thinner in the Vermilion River section (3; marked as a carbonate bed in Figure GS-13-3) than in the Sclater River section (5), where it is significantly thicker. When comparing the Vermilion River section (3) to the 3-27-1-25W1 section, there is very little difference in thickness, with the latter measuring slightly thinner. This variability is likely due to changes in depositional conditions and synformational erosive events.

In theory, correlation of the bentonite beds could be a good tool to help locate a given section, similar to the method described by Bamburak et al. (2012b) for the Pembina Member of the Pierre Shale, but in practice, it is usually not straightforward. The variability in abundance, distribution and thickness of the bentonite beds from one locality to another suggests that nondeposition and/or erosive events have affected the Favel Formation throughout its depositional history. Differences in sedimentary facies and accumulated facies thicknesses at different locations throughout the basin margin could also affect the ability to correlate these beds. Geochronology of the bentonite beds from different locations would serve as the best way to temporally correlate the units, which would also provide the added bonus of linking lateral facies variations through the basin margin.

Figure GS-13-3 shows that stratigraphic positioning of the outcrops to the subsurface is possible and comparing them to a detailed subsurface section is a useful tool. It was determined that the best way to correlate the sections was lithostratigraphically, which is based solely on lithology, by finding the best fit of the lithological pattern to the reference section or other outcrops, while ignoring the thickness variability that can occur between outcrop and subsurface sections.

Economic considerations

The Favel Formation is likely the best prospect as a shale gas resource for Manitoba. It is a thick section of gas-bearing silty and sandy mudstone equivalent to formations with proven gas production records in Saskatchewan and Alberta. In Manitoba, the rarity of core through this section makes it difficult to characterize the formation properly and best determine its true potential, despite the abundance of wireline geophysical information available. Correlation of subsurface information with outcrop information is the best tool available in Manitoba to better characterize the Favel Formation to determine its economic potential.

Acknowledgments

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