



## A Study of Hydraulic Fracture Containment in the Bakken Formation, Southeast Saskatchewan

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### Summary

This abstract presents the latest results of a research project undertaken to develop a better understanding of vertical containment during multistage hydraulic fracturing of tight oil reservoirs in the Bakken Formation, southeast Saskatchewan. Mechanical properties and in-situ stresses have been interpreted from core measurements, wireline logs and diagnostic fracture injection tests. Multistage hydraulic fracturing of a horizontal production well has been simulated using a commercial hydraulic fracture simulator, using the actual treatment schedule as input and using pressure and production data to assess model outputs; in particular, as indicators of height growth. Results suggest the existence of dolomitic layers within the Middle Member of the Bakken Formation which serve as barriers to height growth. However, the effectiveness of these thin barriers is very sensitive to their thickness and dolomite content, both of which are variable.

### Introduction

The Bakken Formation is Upper Devonian to Lower Mississippian in age, and consists of three members. The Upper and Lower Members are black, organic-rich shales that are generally 1 to 10 m thick. The Middle Member contains siltstones and sandstones, and is generally divided into Units A, B and C (oldest to youngest), as shown in Figure 1. In the study area (Viewfield Saskatchewan), light oil is produced from multi-stage, hydraulically-fractured horizontal wells in the siltstones and silty sandstones of Unit A. Given that this reservoir is relatively thin in the study area (Unit A thickness generally < 12 m), a key operational challenge is the creation of hydraulic fractures that are large enough to stimulate production, yet which remains contained within the Middle Member.

### Method

Previous work on the interpretation of rock mechanical properties using core testing results and wireline logging data were reported in Gorjian et al. (2017). Much of the data used had been taken from a well drilled several townships south of Viewfield. In the work reported here, logs from a vertical well ("31/15-18-010-06W2") located in the study area were used as the basis of a new model. Shear wave velocities for this well were estimated using correlations developed by the authors using data compiled for southeast Saskatchewan. Similarly, correlations were used to estimate static elastic properties from log-derived dynamic values, and Biot's coefficient based on effective porosities interpreted using gamma-ray, bulk density and neutron porosity logs. Horizontal stresses were calculated using equation (5) in Warpinski (1989), calibrated (with a tectonic strain of 0.00015) to match minimum horizontal stress magnitudes from DFIT test results. Using these data as inputs, in addition to geological structure and well trajectories extracted from public data and fracture fluid and proppant rates and properties recorded during field operations, a model of an 8-stage hydraulic fracture treatment conducted following standard practices in the area (circa 2008) was developed using GOHFER version 8.2.6.1 (Figure 2). Further to modeling actual (base case) conditions, sensitivity analyses were conducted to assess the effects of barrier thickness, mechanical properties (Poisson's ratio, which in turn affects horizontal stresses), fluid

viscosity and proppant tonnage. Results were interpreted with context provided by an isopach map of dolomitic layer thickness (as interpreted from conventional logs for vertical wells throughout the study area), dolomite contents reported in wellsite geology logs, and interpretations of hydraulic fractures which remained in zone (FIZ) versus those that grew out-of-zone (FOOZ) inferred from experience-based rules of thumb using water-cut and production rate data (supplemented where available using produced water isotopic analyses).

## Results

Figure 3 shows log data and mechanical properties interpreted for the vertical well (31/15-18-010-06W2) during this project. Key points observed from Figure 2 are the following:

- The log-derived Poisson's ratio measurements suggest that Poisson's ratio is low (for the most part) in the Upper and Lower Bakken shales, relative to Poisson's ratio in the Middle Bakken. Results suggest these shales might not serve as effective barriers to fracture growth.
- There are relatively thin zones near the top and base of the Middle Bakken possessing relatively high horizontal stresses. A key outcome of this observation, which has been investigated via sensitivity analysis, is the fact that these thin zones serve as barriers to fracture growth - though only up to a certain point.

An example of the results generated using the fracture simulator (base case scenario, using mechanical properties and stresses depth-shifted from the vertical well, and an average proppant mass of 9 tonnes per stage) is given in Figure 4. Surface pressures predicted by the simulator compare favourably to pressures recorded during field operations, which improves confidence in the model (Figure 5). In this case, the simulator predicted fracture growth fully through the upper dolomitic barrier and the Upper Bakken shale, thus establishing hydraulic communication with the overlying water-bearing Lodgepole Formation, and growth part way through the lower dolomitic barrier and shale. These results are consistent with production data for this well, which suggest significant production of Lodgepole water. Additional, broader-scale analyses throughout the general area further suggest a greater number of out-of-zone hydraulic fractures in areas where the upper dolomitic barrier is relatively thin and/or has lower dolomite content.

Sensitivity analysis results suggest that fracture containment could be achieved for proppant tonnages in the 3 to 4 tonnes range, especially if fracture fluid viscosities can be reduced slightly (~20%) compared to values used historically. Additional sensitivity analyses revealed that breakthrough tendency (upwards versus downwards) is extremely sensitive to the relative thicknesses and Poisson's ratios of the upper and lower barriers.

## Conclusions

The results from simulation, log analysis and production data all suggest that a dolomitic layer near the top of the Middle Member of the Bakken Formation has a strong influence on the potential for height growth into the Lodgepole Formation. However, additional work is still required to answer the following questions:

- What are the effects of layer thickness and dolomite content, and what are the attributes and effectiveness of the layer near the base of the Middle Bakken?
- What are the effects of stress shadows on effectiveness of upper and lower dolomitic barriers for containing hydraulic fractures in the Middle Bakken?

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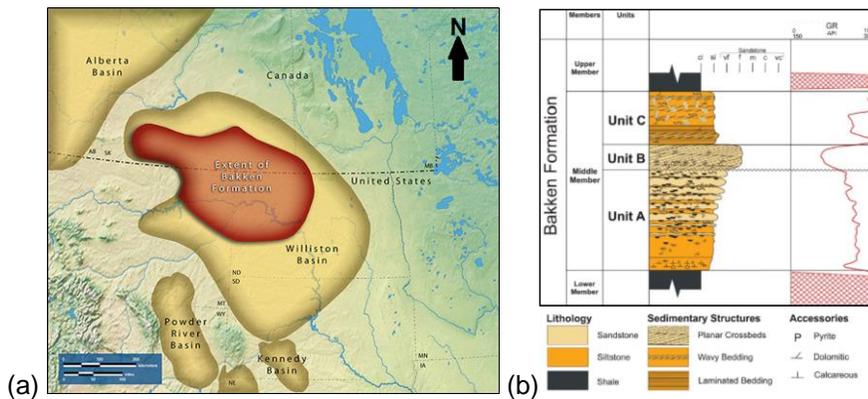


Figure 1: (a) Map showing extents of the Bakken Formation (N.E.B., 2015). (b) Stratigraphy of the Bakken Formation in southeast Saskatchewan (after Kohlross and Nickel, 2013).



Figure 2: Geological structure of the Bakken Formation in a horizontal well in the Viewfield area. Colours represent minimum horizontal stress magnitude, yellow line denotes well trajectory and green squares denote perforations.

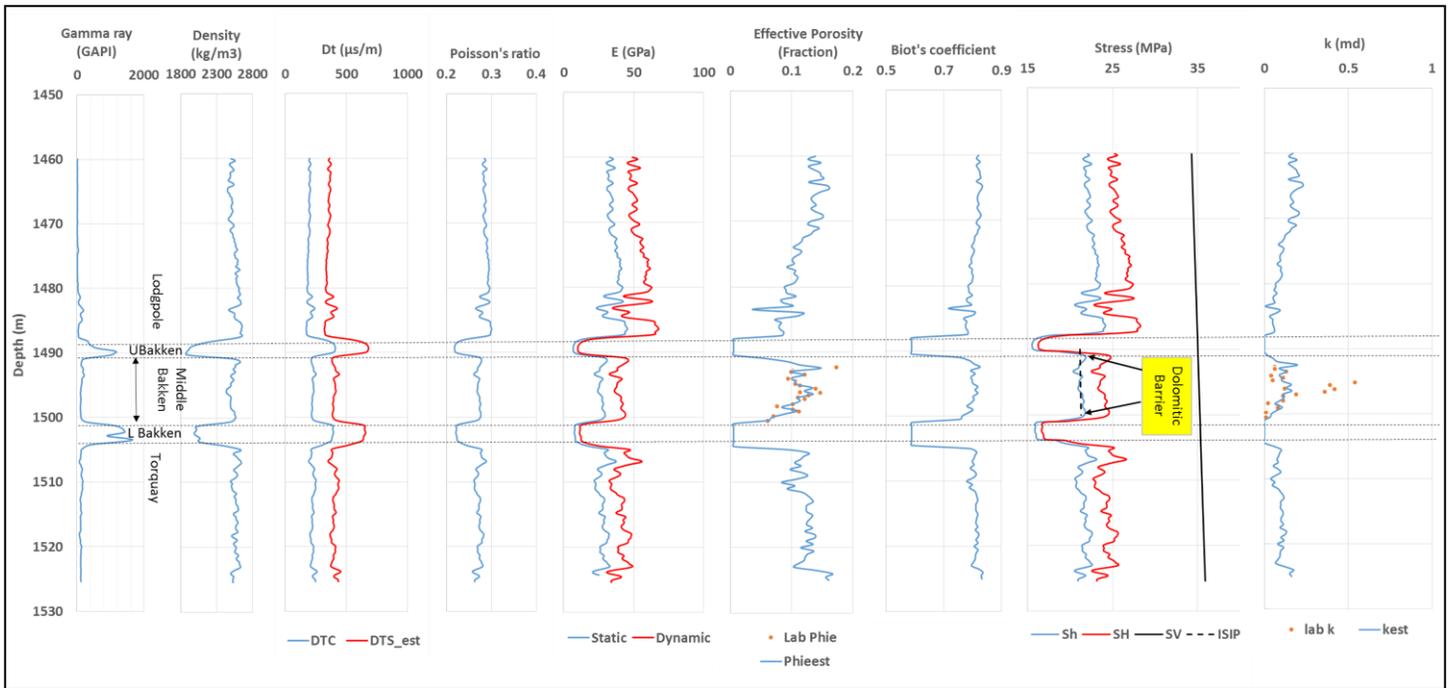


Figure 3: Selected wireline log data, log-calculated mechanical properties for 31/15-18-010-06W2.

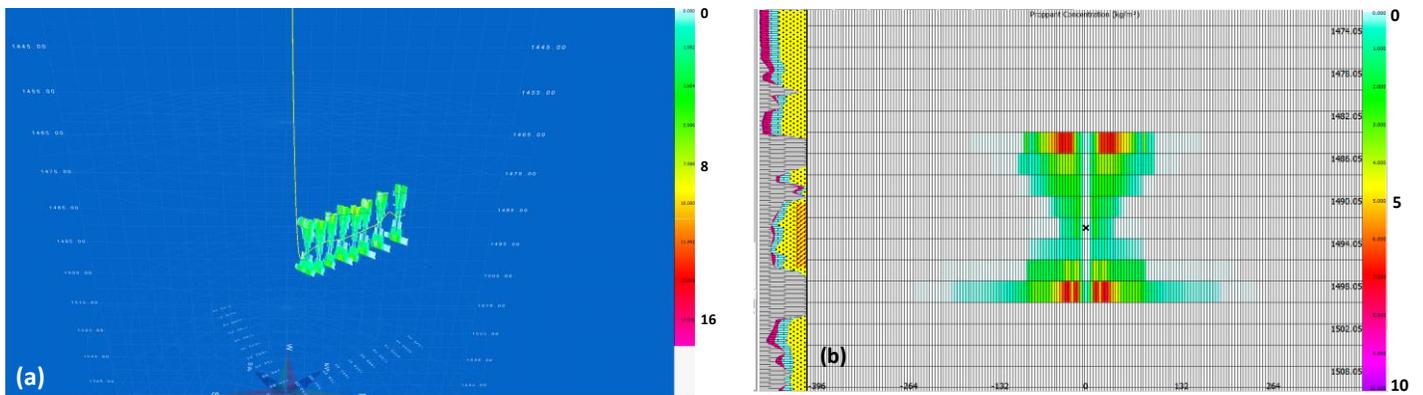


Figure 4: (a) Simulated proppant concentration ( $\text{kg}/\text{m}^2$ ) at the end of multistage hydraulic fracture (8 stages). (b) Proppant concentration ( $\text{kg}/\text{m}^2$ ) within the hydraulic fracture for stage 5.

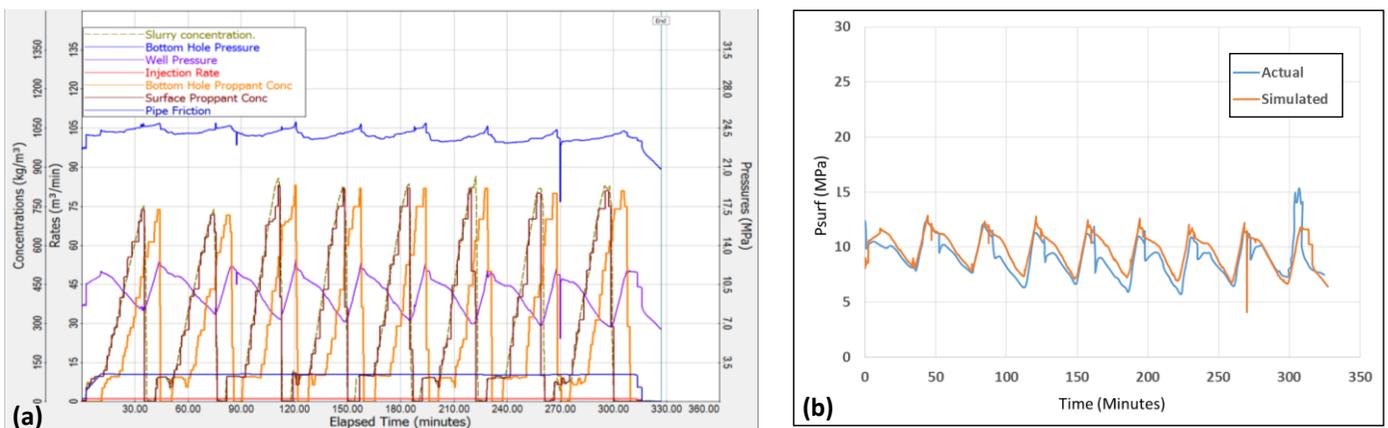


Figure 5: (a) Actual and simulated hydraulic fracture treatment schedule. (b) Actual and simulated pressures.