Conventional Trapping in Unconventional Reservoirs; A Bakken Case Study

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Introduction

Increasing variance in commodities pricing has forced significant cost cutting across the industry, particularly from exploration budgets and research and development. Cost cutting forces producers to find creative ways to minimize risk. This paper focuses on the petroleum system of the established Viewfield Pool in southeastern Saskatchewan with an emphasis on trapping mechanisms and reservoir properties. Drilling established plays like the Viewfield Pool is a low risk idea suitable for the current economic climate.

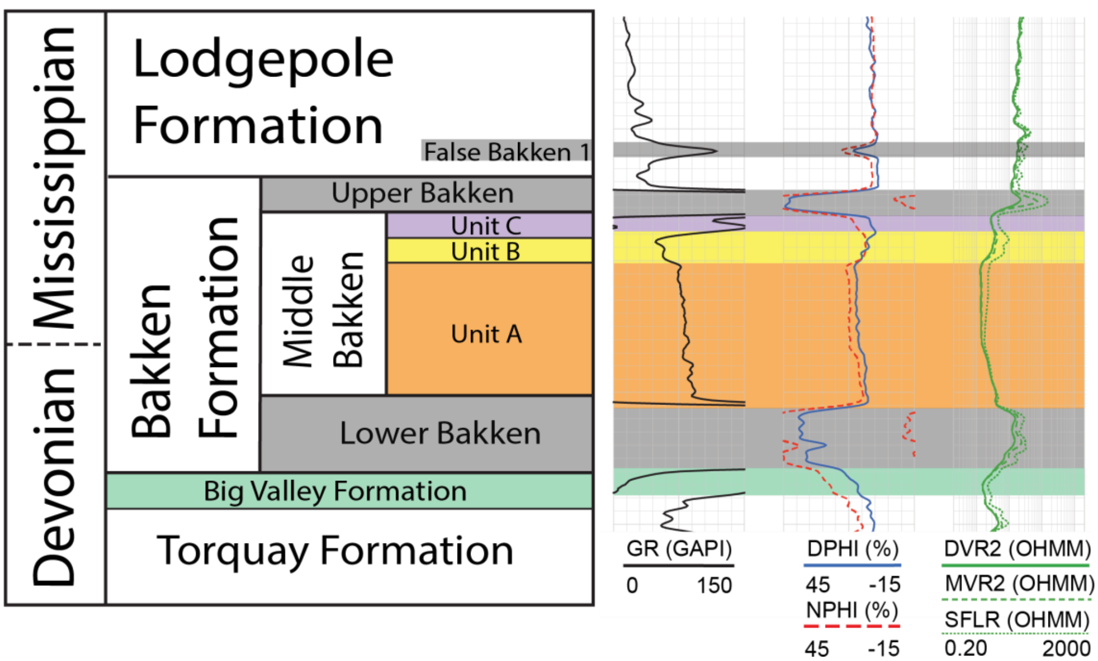

Figure 1: A stratigraphic column and associated type log from well 16-01-006-09W2 illustrating the relationships of the various depositional units examined in this study.

Rock-Evaluation (Aderoju and Bend, 2013) and vitrinite reflectance (Osadetz & Snowdon, 1995) data show the Bakken Formation in this study area, is immature to sub-mature; indicating hydrocarbons trapped within many Canadian plays must have migrated from deeper parts of the Williston Basin. This is in contrast to the US portion of the Bakken play, which is generally thermally mature to over-mature. The majority of plays are the result of in-situ, self sourced hydrocarbon generation, and are generally over pressured (Sonnenberg, 2010).

Integrating a recently developed stratigraphic model with additional data sets presented in this paper reveals a simple stratigraphic pinch out to be the primary method of hydrocarbon trapping, with some caveats. This is in contrast to the proposal by Kohlruss (2009, 2011) where a combination of stratigraphic trapping beneath Units B and C, along with the low permeability of Unit A itself is responsible for the Viewfield accumulation. Stratigraphic nomenclature can be found in figure 1.

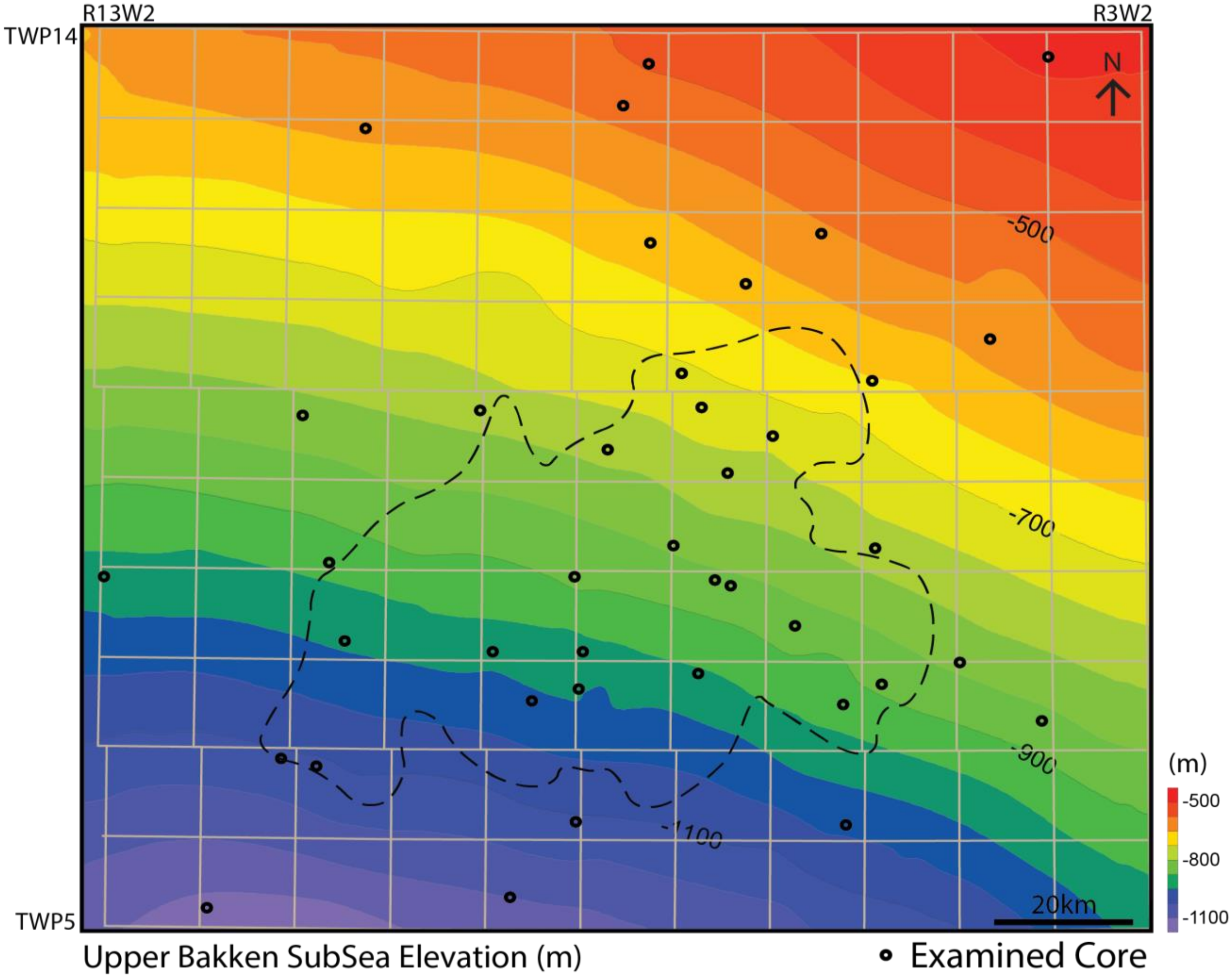

Figure 2: A structure map of the top of the Upper Bakken Formation. Note the general dip direction to the S, SW. Core examined for this study are shown as circles (⊙). The Viewfield Pool is outlined in black.

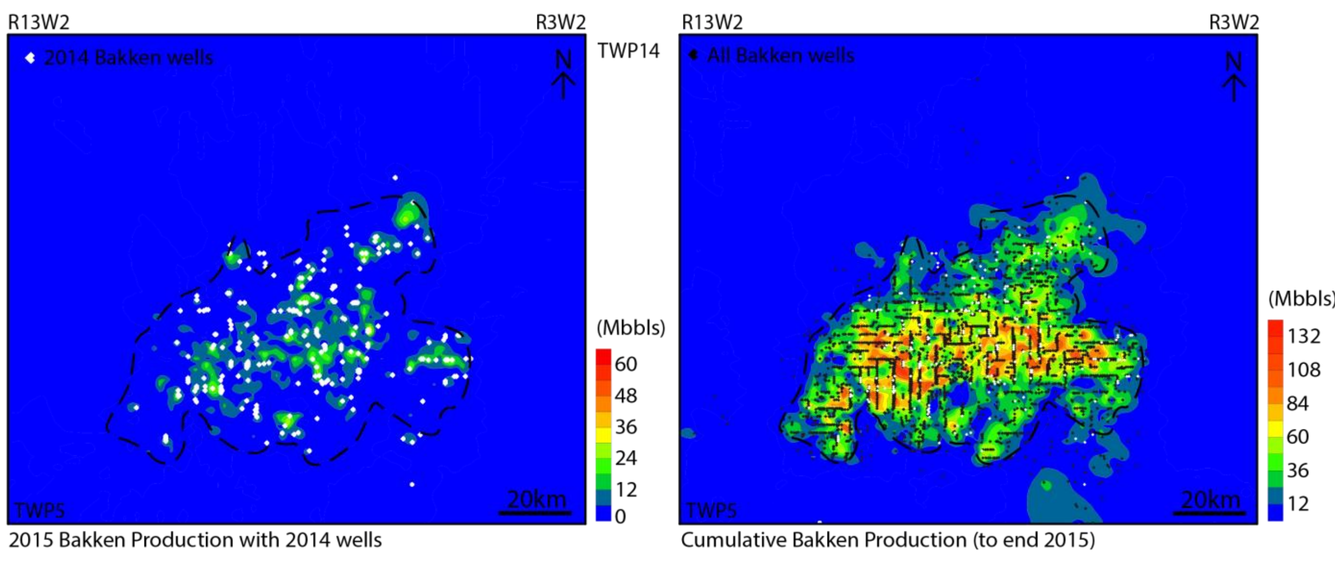

Figure 3: Contoured production data from the Bakken Formation. The black dashed line outlines the Viewfield Pool. The map on the left displays 2015 oil production with new wells drilled in 2014. The map on the right displays cumulative oil production to the end of 2015. Note most new wells are infills.

Methods

To build a depositional model of the Bakken Formation, a formal study area (figure 2) spanning from TWP5 to TWP14 and R3 to R13W2, and encompassing the Viewfield Pool, was established. A selection of 40 slabbed cores were selected and analyzed using conventional core logging methods. Publicly available core analysis data from the 40 cores, constituting 572 unique data points, was calibrated to the stratigraphic model. Isopach maps illustrating the stratigraphic model were created from 425 wells within the study area.

This area has ~3700 wells targeting the Bakken Formation as of January 2016. Of these 3700 wells, ~210 were completed in 2015. Production data from these wells was analyzed using contour maps (figure 3) and cross plots. Most wells have been infills, but drilling along the periphery of the pool is common. Converting production wells to water injection wells for secondary recovery is common.

Element mapping using SEM, and thin section petrography was used to determine diagenetic controls on the reservoir. Pore throat size from both inside and outside the productive area was estimated from SEM images. DST pressures were plotted to determine pressure gradients and look for isolated sedimentary bodies.

Results and Discussion

A simplified stratigraphic model is presented in figure 4, along with isopach maps of the various depositional units. A clear stratigraphic pinch out of Unit A occurs in the northern and eastern portions of the study area. This pinch out coincides with diminished production.

A cross plot of porosity and permeability of Unit A reveals both parameters are relatively consistant across the study area. The productive area of the pool has similar porosity (6 – 14%) and permeability (.08 - .6 mD) trends to the unproductive areas north of the pool. This suggest lower permeabilities in the reservoir interval, up dip of the pool, are not responsible for hydrocarbon trapping. Additionally, the suggestion that the low permeability of Unit A prevented oil from being flushed from the Viewfield Pool by formation waters (Kohlruss, 2011) is contradicted by the implementation of very successful secondary recovery by waterflooding. A visual estimaton of the dominant pore throat size (5 - 30µm) in Unit A shows no distinction between samples from inside or outside the pool.

Limited DST data shows two distinct pressure gradients for wells within the productive area, and wells surrounding the productive area north of the oil/water contact. This suggests either some compartmentalization, or fluid communication with other formations. A hydrostatic pressure gradient of 0.436 psi/ft suggests the Viewfield Pool is slightly under to slightly over pressured.

Oil saturations from core analysis data are similar in the productive area, and the unproductive areas north of the oil/water contact. Cumulative oil production ranging from 1000 to 9000 barrels occurs in 4 wells north of the Viewfield Pool, demonstrating significant volumes of oil are present in this area. 19 barrels were produced from well 04-11-014-08W2 at the up dip pinch out of Unit A, and 0 barrels were produced from well 05-24-014-08W2 just north of the pinch out.

Conclusions

A number of unique data sets provide evidence that the Viewfield Pool is a simple stratigraphic pinch out of Unit A. This pinch out occurs where the heterolithic mud dominated Unit C, converges with the Lower Bakken Member, seperated only by a combined sequence boundary and transgressive surface. It is here that the heterolithic mud dominated Unit C directly overlies organic rich mudstone of the Lower Bakken Member, just up dip from the Viewfield Pool. Production near this pinch out is hindered by a very thin stratigraphic succession that limits the drillers ability to contain fractures, combined with significantly reduced reservoir thickness. Given the immense thermally mature source rock directly down dip of the pool, along with up dip oil accumulations such as the Rocanville Pool, it is safe to assume that the entire stratigraphic trap has been filled to spill point.

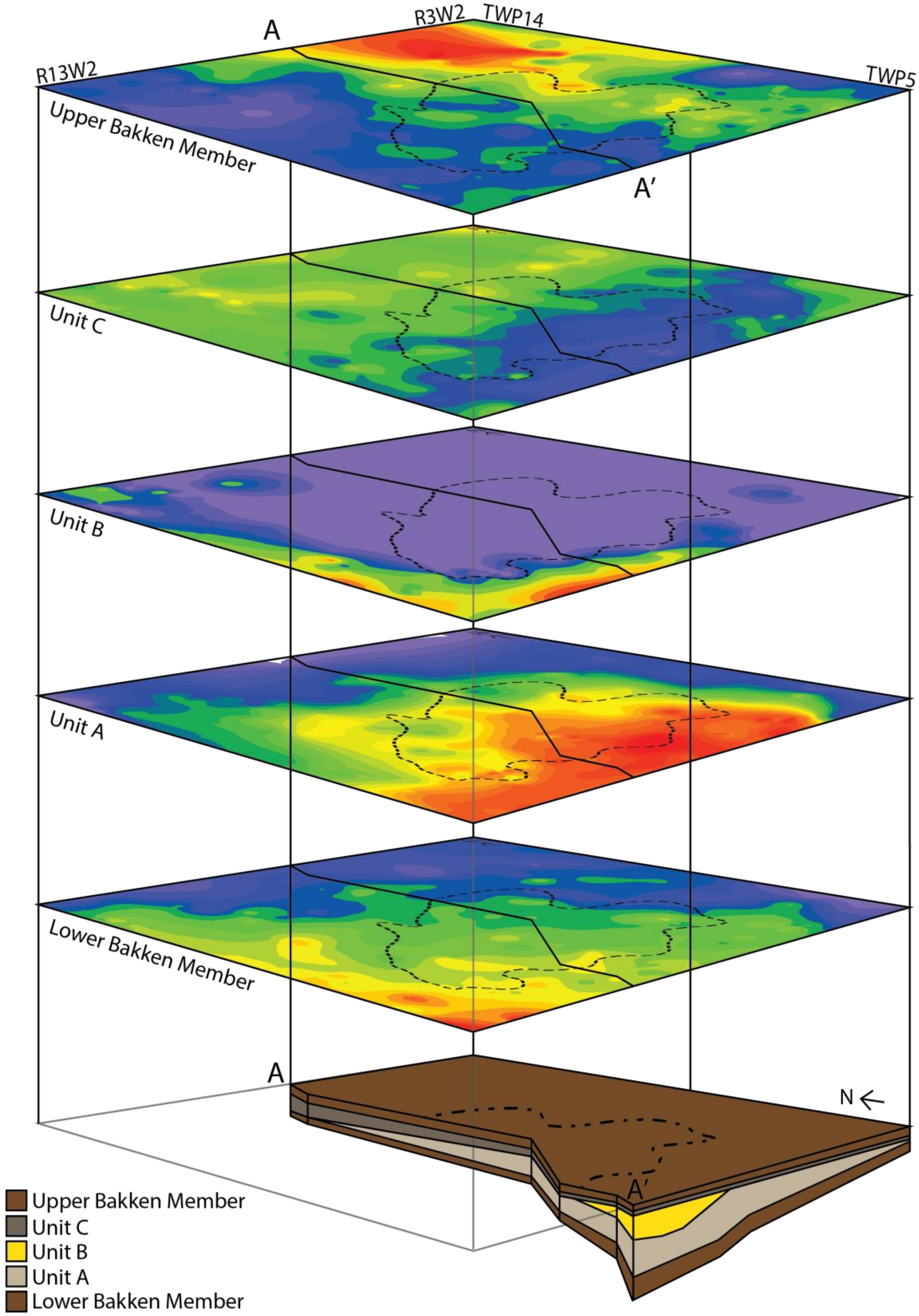

Figure 4: A 3D model of the Bakken Formation with isopach maps for the Upper and Lower Bakken Members, and Units A, B, and C, overlain. The Viewfield Pool is outlined by a black dashed line. Note the pinch out of Unit A towards the north on a cross section cut A to A', as well as the eastward pinch out.

References

Aderoju, T.E. & Bend, S.L., 2013. A Rock-Eval evaluation of the Bakken Formation in southern Saskatchewan; in Summary of Investigations 2013, Volume 1, Saskatchewan Geological Survey, Sask. Ministry of the Economy, Misc. Rep. 2013-4.1, Paper A-2, 14p.

Kohlruss, D. & Nickel, E., 2009. Facies analysis of the Upper Devonian-Lower Mississippian Bakken Formation, southeastern Saskatchewan; in Summary of Investigations 2009, Volume 1: Saskatchewan Geological Survey, Saskatchewan Ministry of Energy and Resources, Miscellaneous Report 4.1, Paper A-6, 11p.

Kohlruss, D., & Nickel, E. H., 2011. The Middle Bakken Member in Southeastern Saskatchewan: Viewfield and Beyond. Williston Basin Symposium.

Osadetz, K. G. & Snowdon, L. R., 1995. Significant Paleozoic petroleum source rocks in the Canadian Williston Basin: their distributions, richness and thermal maturity (Southeastern Saskatchewan and Southwestern Manitoba). Geological Survey of Canada Bulletin 487

Sonnenberg, S. A., 2010. PS Abnormal Pressure Analysis in the Bakken Formation, Williston Basin, a Key to Future Discoveries. 2010 Annual AAPG Meeting Abstracts, p. 242.