Oil and Gas Potential of the Red River Formation, Southwestern North Dakota

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Introduction

North Dakota has experienced commercial oil and gas production from 19 different geologic formations over the past 65 years. Most of these productive formations have experienced spotlight attention from the oil and gas industry at one time or another, and, whether for a few months or years, were considered a "hot play" to explore and develop. The unconventional Bakken-Three Forks development is a current example of a play that brought oil and gas activity in the state to record levels and has sustained drilling activity even in a depressed oil and gas market. As the oil and gas industry transitions beyond the Bakken over time and begins to spend more time evaluating the other 17 productive non-Bakken/Three Forks Formations, additional oil and gas plays will emerge across western North Dakota. One formation that has previously experienced "hot play" status and may be poised to one day re-emerge into the spotlight of the oil and gas industry is the deeply buried Red River Formation.

Over 1,300 vertical and horizontal Red River wells have combined to produce more than 300 million barrels of oil from North Dakota (fig. 1). The Red River's cumulative oil production is the third highest for the state, a bronze medal so to speak, and is only eclipsed by the "gold" medal Bakken-Three Forks Formations (>1.2 billion barrels of oil) and the "silver" medal Madison Group (Mission Canyon & Charles Formations, ~1 billion barrels of oil). Red River production is also regionally extensive and stretches into northwestern South Dakota, eastern Montana, and southern Saskatchewan (fig. 1).

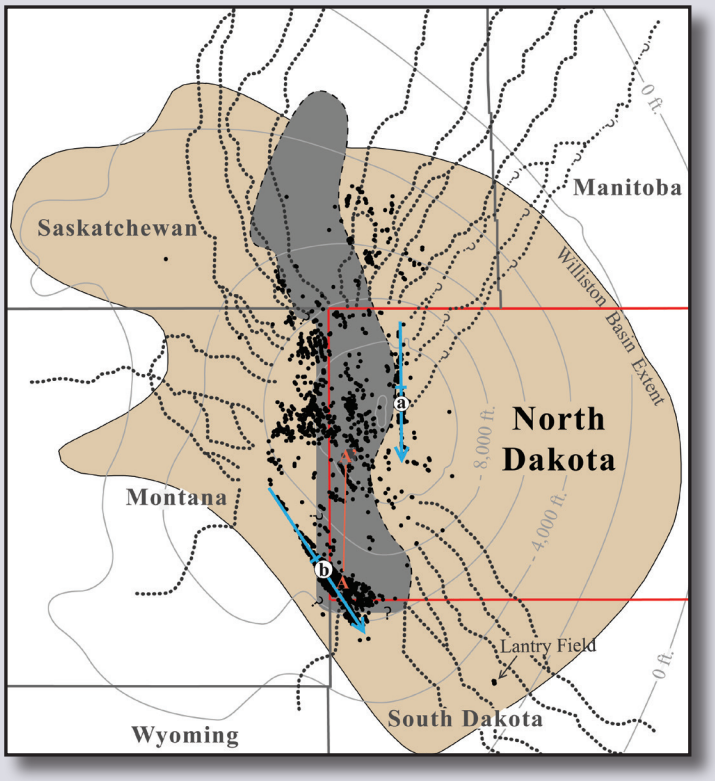

Figure 1. Regional Red River oil and gas well production map. Black dots represent Red River oil and gas productive wells. The dark grey represents the extent of Red River kukersites (source beds). The black dotted lines represent hydrocarbon (oil and gas) migration pathways modeled by Khan and others (2006), where oil and gas move up dip from the central portions of the Williston Basin (middle of the figure). Light grey lines represent structure contours (sub-sea level) on the Red River Formation top. The North Dakota state border is colored red. A-A' displays the location of the figure 2 cross-section. a = Nesson Anticline, b = Cedar Creek Anticline

Summary of Red River Oil and Gas Production

The upper Red River consists of four, vertically stacked, oil-productive sedimentary rock layers referred to informally as the "A" through "D" zones (fig. 2). Just over half of the Red River's oil production has come from horizontal wells drilled within the "B" zone of southwestern Bowman County, a prolific oil play that emerged during the late 1990s and was North Dakota's "hot play" before the Bakken emerged. Most of the remaining Red River production has been from vertical wells completed in the underlying "C" and "D" zones, which stretch across the western quarter of the state (fig. 1). The Red River's oil and gas is believed to be sourced by kukersites, which are relatively thin (<2 ft. thick), but highly organic-rich petroleum source beds within the "D" zone (fig. 2) (Nesheim, in press). A recent study has estimated that these kukersites have combined to generate over 50 billion barrels of oil beneath western North Dakota (Nesheim, in press). Cumulative Red River production from across the entire Williston Basin totals roughly 750 million barrels of oil equivalent, which only accounts for a fraction of this generated volume. Therefore, the Red River may still hold tens of billions of barrels of oil, and while numerous prospective areas exist for continued Red River exploration, one area that appears to be substantially underexplored occurs within southwestern North Dakota.

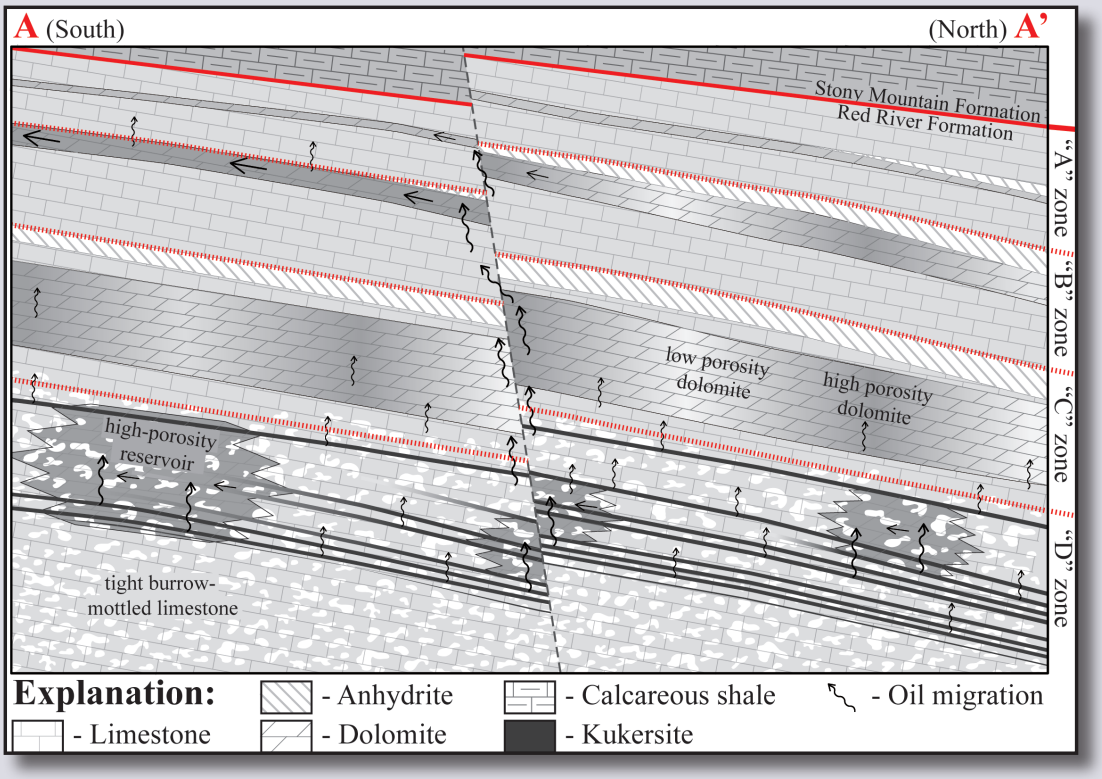

Figure 2. Schematic north-south cross-section of the upper Red River Formation depicting the four oil and gas productive "A" through "D" zones. The location of A-A' is displayed on figures 1 and 3.

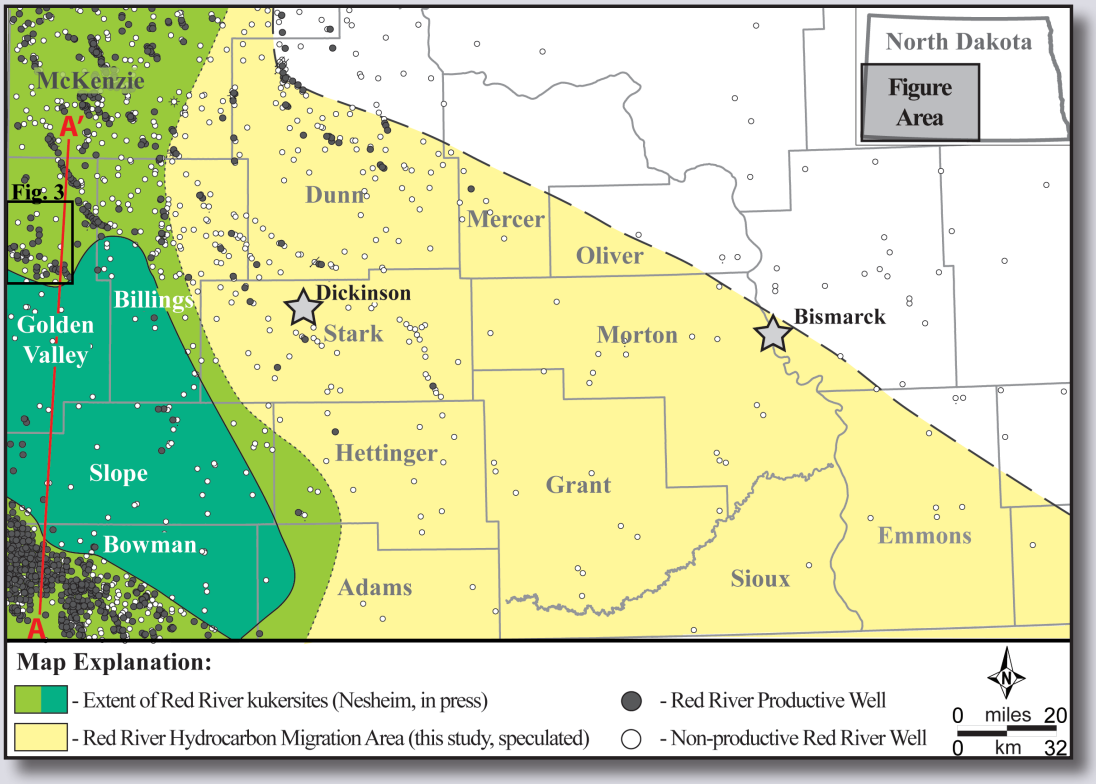

Figure 3. Red River oil and gas production map for southwestern North Dakota showing the extent of Red River kukersites (green) and a speculated area of southeastwards Red River hydrocarbon migration (yellow) that trends towards the Lantry Field of central South Dakota (see fig. 1). The dark green area represents the proposed under-explored area for Red River oil and gas.

A New Exploration Model

Technological advances in the oil and gas industry have not only been applied to horizontal drilling in North Dakota, but have also aided vertical well exploration as well. During the early 2010's, Whiting Oil and Gas Corporation (Whiting) reportedly used 3D seismic to identify more than 50 vertical Red River prospects within their Big Valley play of Golden Valley County that consist of localized porosity anomalies (Oil & Gas Journal, 2012) within the Red River "D" zone, similar to previously described and modeled features by Longman and others (1983). The Red River "D" zone also contains thermally mature kukersites, as previously mentioned, which have reached the peak to late mature stages of oil generation across Golden Valley County (fig. 3). Therefore, the localized porosity anomalies identified are likely locally sourced with oil and gas from the interbedded kukersites (e.g. fig. 2).

Twenty-one Red River wells had been drilled in the area prior to Whiting's recent activity (pre-2011) (fig. 4). Seven of those legacy wells were completed in Red River reservoirs and produced oil, a success rate of 33%. Six of those productive wells yielded production totals ranging from 108,000 to >250,000 barrels of oil, and one well produced only ~8,600 barrels of oil.

From 2011-2013, Whiting drilled a total of 27 vertical Red River wells in the Henry-Camel Hump field area targeting high porosity anomalies identified using

3D seismic (fig. 4). Twenty of their wells were completed and produced oil for a success rate of 74%, more than double the rate of the legacy wells drilled without 3D seismic. However, commercial success of Whiting's Red River wells has been variable. Approximately six of their wells have excellent vertical well estimated ultimate recovery volumes of over 300,000 barrels of oil per well while the remaining 14 producers range from 120,000 to <30,000 barrels of oil per well for estimated ultimate recovery* (fig. 4). The Camel Hump Field proved to be the best Red River acreage in the area to date with a 6 out of 7 success rate, five of which appear to have estimated ultimate recovery volumes of >300,000 barrels of oil. For the remaining, non-Camel Hump area, the success rate was slightly lower (14 of 20, 70%) and most of the estimated ultimate recovery volumes were only between 60,000 and 120,000 barrels of oil per well. Overall, Whiting's recent Red River wells in Golden Valley County combine for roughly 3.7 million barrels of oil in estimated ultimate recovery, and average 190,000 barrels of oil per vertical well.

*Estimated Ultimate Recoveries (EUR's) were calculated by the author using current oil production decline with ~3-4 barrel of oil per day cut offs. Additional bypassed pay, well reworking/restimulation, and/or secondary recovery efforts may yield additional reserves.

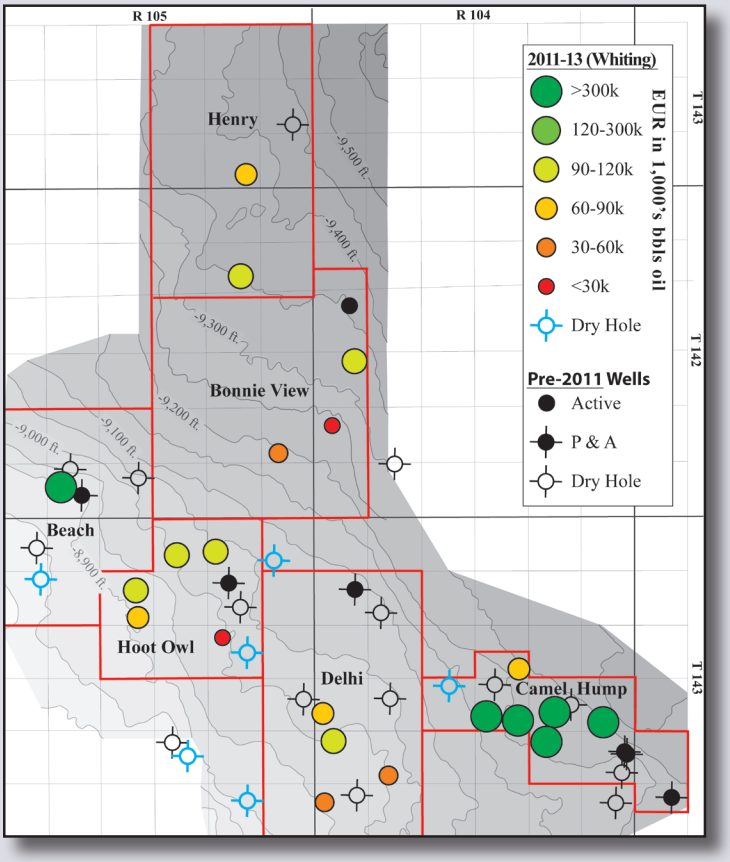

Figure 4. Field map of the North Dakota portion of Whiting's Big Valley prospect area. The grey-colored lines and shading represent structure contouring of the Red River Formation top derived from 3D seismic that was stitched together from several Oil and Gas Division hearing exhibits. Oil and gas field boundaries are outlined in red with field names in black text.

The Next Step

Portions of southwestern North Dakota (southern Billings, Golden Valley, Slope, and northeastern Bowman counties) contain areas underlain by thermally mature kukersites (oil source) and a handful of dispersed Red River producers. This area has a very low overall well density, a similar scenario to the Henry-Camel Hump field area before Whiting's recent activity (fig. 3). Whiting's Big Valley Red River play spanned roughly 100 square miles and has yielded 28 Red River producers to date (both new and legacy wells) with a combined estimated ultimate recovery total of nearly five million barrels of oil (~178,000 barrels of oil per well). Assuming the 3D seismic porosity anomaly exploration technique can be further applied to the Red River, the proposed under-explored area (~2,400 square miles) holds the potential for 100s of vertical wells and 10s of millions of barrels of oil production. There have been 83 Red River well penetrations within the under-explored area, 17 have produced oil for a ~20% success rate, similar but slightly lower than the legacy wells in the Henry-Camel Hump field area.

The use of 3D seismic to identify Red River "D" zone porosity anomalies may also lead to future development northwards of the Camel Hump-Henry field area. Red River production and thermally mature kukersites both extend northwards up to the Saskatchewan border, where Bakken-Three Forks activity dominates the landscape. Most of the legacy Red River wells drilled along this trend were likely positioned using only 2D seismic to identify structural highs. 3D seismic application should add additional Red River vertical well targets across the Bakken-Three Forks development area. Also, due to the thermally mature source beds (kukersites) that have generated 10s of billions of barrels oil, the Red River holds the potential to one day emerge as a Bakken-like resource play.

References

Khan, D.K., Rostron, B.J., Margitai, Z., and Carruthers, D., 2006, Hydrodynamics and petroleum migration in the Upper Ordovician Red River Formation of the Williston Basin: Journal of Geochemical Exploration, v. 89, p. 179-182.

Longman, M.W., Fertal, T.G., and Glennie, J.S., 1983, Origin and Geometry of Red River Dolomite Reservoirs, Western Williston Basin: American Association of Petroleum Geologists Bulletin, v. 67, no. 5, p. 744-771.

Nesheim, T.O., in press, Stratigraphic and geochemical investigation of Kukersites (petroleum source beds) within the Ordovician Red River Formation, Williston Basin: American Association of Petroleum Geologists Bulletin.

Oil and Gas Journal, 2012, Whiting pursues Williston basin Red River play: http://www.ogj.com/articles/2012/08/whiting-pursues-williston-basin-red-river-play.html, (retrieved August 27th, 2012).