Review of the TI-WAO- 157-95-14H-1: The First Middle Lodgepole Unconventional Test Well in the Williston Basin

Timothy O. Nesheim

Introduction

Unconventional-style completions (horizontal drilling coupled with hydraulic fracturing) have become a new standard within the oil and gas industry. This drilling and completion technique unlocked the prolific Bakken-Three Forks play, which has received the lion's share of drilling activity and media attention in North Dakota. Also, with production rates nearing 1.5 million barrels per day and billions of barrels of technically recoverable oil, the Bakken-Three Forks is a world-renowned resource play. In addition to the Bakken-Three Forks, there have been several other formations tested during recent years using unconventional completions in North Dakota, including the Spearfish, Tyler, Charles/Mission Canyon (Midale-upper Rival), and Red River Formations. Some of these units have yielded commercially viable results and have experienced some level of sustained exploration and development, such as the Spearfish and Midale-Rival plays. Others have yielded some oil and gas, but at lower production rates. These uncommercial tests include the Tyler and Red River Formations, which still have future potential as unconventional plays, but may be waiting for better economic conditions as well as advances in completion technology and/or revised geological knowledge.

One unconventional test with interesting, encouraging results was the TI-WAO- 157-95-14H-1 (TI-WAO), a middle Lodgepole horizontal well located in eastern Williams County (fig. 1). The TI-WAO was drilled in 2013 and initially completed in 2014, when oil prices were generally high (>$80/barrel West Texas Intermediate). Sustained and continued production, however, did not begin for the TI-WAO until mid-2015, after oil prices plummeted beginning in late 2014. The TI-WAO may not have set any initial production-rate records, but it does represent the first unconventional test of the middle Lodgepole, which is a very poorly understood and untapped reservoir interval within the Williston Basin.

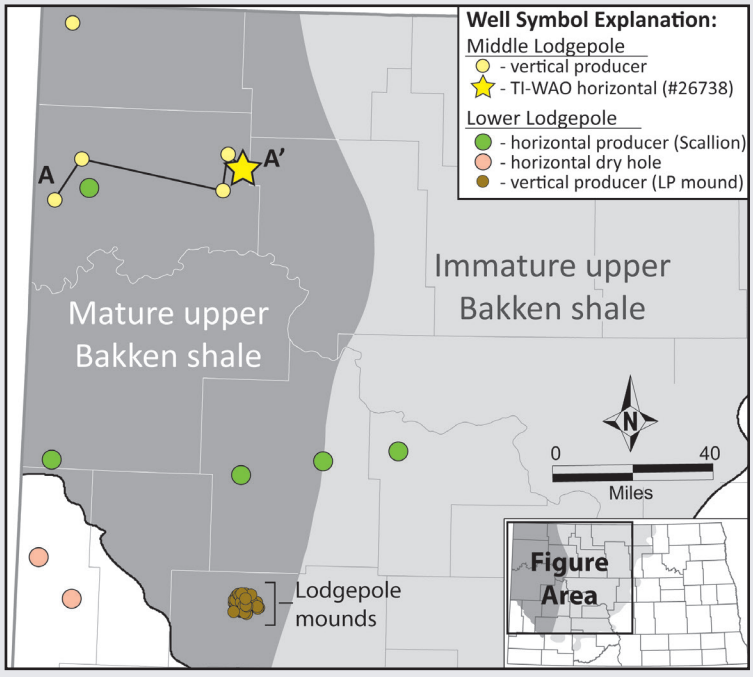


Figure 1. Map of northwestern North Dakota showing the distribution of Lodgepole Formation oil and gas wells. The upper Bakken shale extent is from LeFever (2008). A-A' shows the location of the figure 2 cross-section.

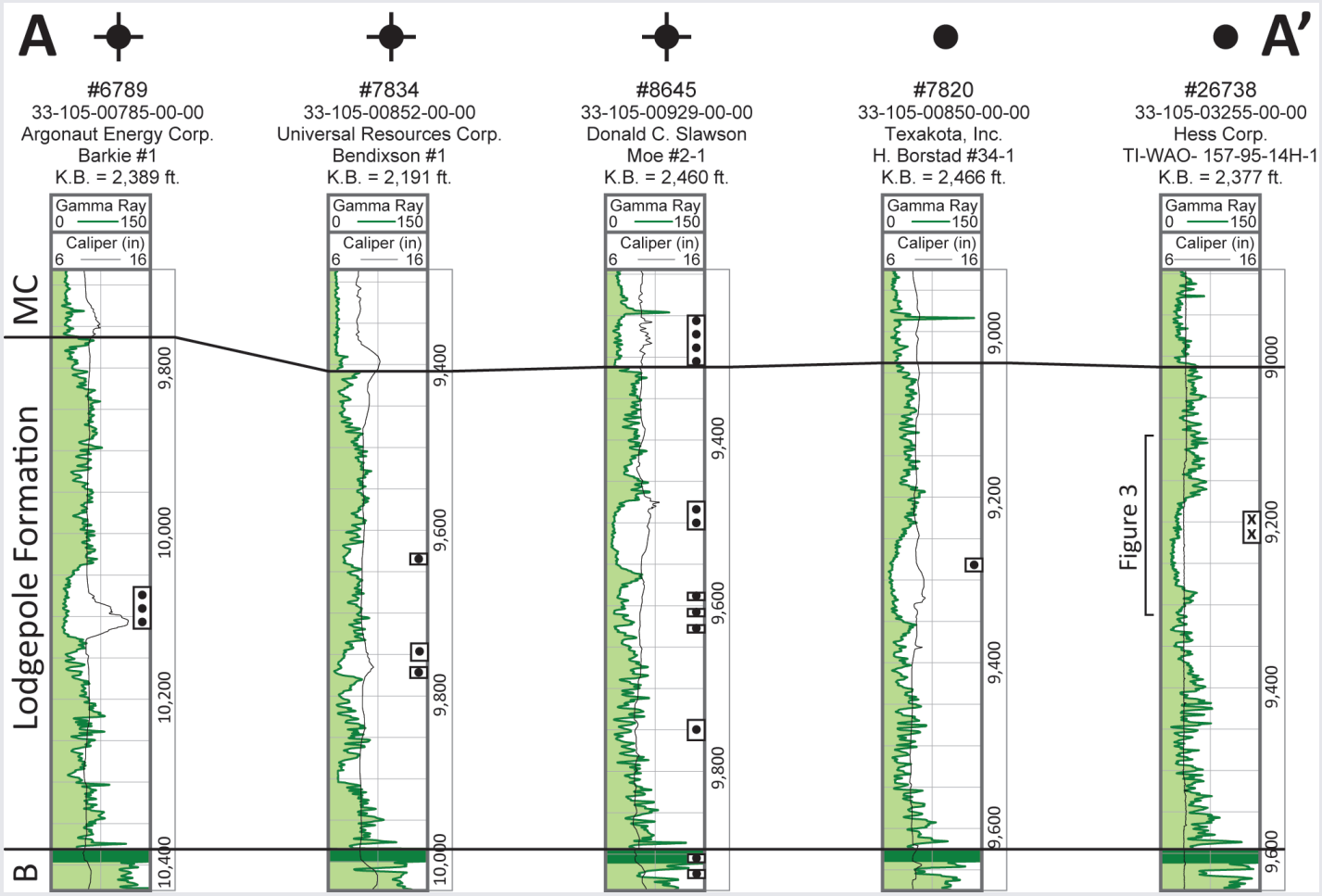


Figure 2. Stratigraphic cross-section of the Lodgepole Formation showing the perforated intervals (outlined black dots) from vertical Lodgepole wells in northwestern North Dakota, and the approximate horizontal target zone of the TI-WAO-157-95-14H-1 (outlined black Xs).

Petroleum Production History of the Lodgepole Formation

Following the initial discovery of oil in North Dakota in 1951, the Lodgepole was not known as an important oil producing interval for the first several decades of exploration and development in the Williston Basin. During those early decades, ony a handful of vertical wells (five) produced minor to moderate amounts of oil from Lodgepole reservoirs in northwestern North Dakota (figs. 1 and 2).

Then, in the 1990s, the Lodgepole mounds play erupted in the Dickinson area (fig. 1). Vertical wells with initial production rates of over 2,000 barrels of oil per day began to emerge which produced from Waulsortian-type mounds located at the base of the Lodgepole, just above the upper Bakken shale (Burke and Diehl, 1993; 1995). Many of those wells have cumulatively produced over one million barrels of oil per well and are still actively producing under water floods (enhanced oil recovery). More recently, as the Bakken-Three Forks play emerged, a handful of horizontal test wells have been drilled and completed in the Scallion subinterval (Scallion) of the lower Lodgepole, also positioned directly over the upper Bakken shale. Several of those unconventional Scallion wells have achieved sustained oil and gas production rates, enough to keep the wells active, but not at high enough rates yet to achieve sustained developmental drilling activity. The Scallion and the Waulsortian-type mounds share approximately the same stratigraphic position at the base of the Lodgepole, directly over the upper Bakken shale, but have different spatial distributions and reservoir rock types. The Waulsortian mounds occur in only a few, spatially limited areas whereas the Scallion is more laterally continuous and regionally expansive. The Waulsortian mound reservoirs are moderately porous and permeable skeletal limestone (Burke and Diehl, 1995) whereas the Scallion is comprised of dense limestone with lower porosity and permeability (Mackie, 2013). Despite the drilling activity in the Scallion and Waulsortian mounds, little activity has occurred within the middle and upper portions of the Lodgepole section.

Drilling and Completion of the TI-WAO- 157-95-14H-1

The TI-WAO was spudded on December 6th, 2013 in the Tioga Field of eastern Williams County by Hess Corporation (fig. 1). A total depth (TD) of 13,625 feet was reached on May 16th, 2014, which included a ~4,400-foot lateral positioned within the middle Lodgepole Formation at depths approximately 400 feet above the upper Bakken shale (figs. 2 and 3).

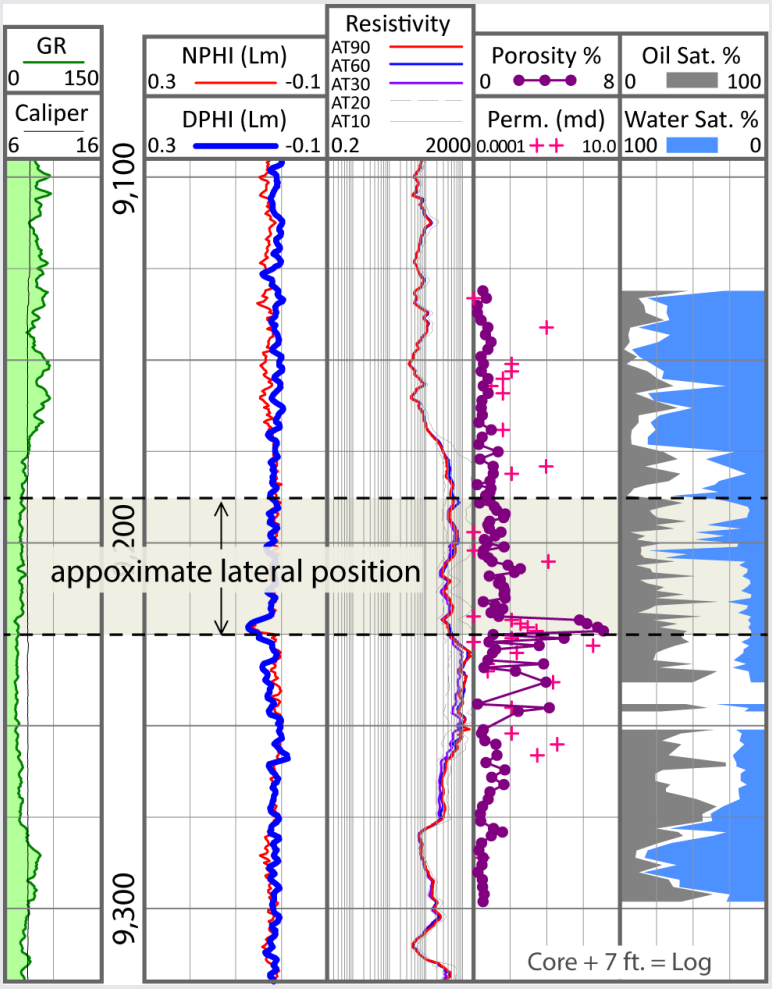


Figure 3. Wireline logs and standard core-plug data (permeability, porosity, oil and water saturations) from the middle Lodgepole Formation for Hess's TI-WAO-157-95-14H-1 (NDIC: 26738, API: 33-105-03255-00-00, Sec. 14, T157N, R95W). The stratigraphic (depth) position for the displayed interval is indicated on the figure 2 cross-section.

The TI-WAO was completed on July 18th, 2014 with an acid frac consisting of 37 stimulation stages and 14,782 barrels of fluid (15% acid) with no reported proppant. The initial production rate reported consisted of 103 barrels of 44.5 API gravity oil and 148 barrels of water over a 24-hour period. During its first full month of production in May of the following year, the TI-WAO averaged 111 barrels of oil, 96 barrels of water, and 162 thousand cubic feet (MCF) of gas per day (fig. 4a). Recent oil production from the TI-WAO has been relatively steady at 12-15 barrels per day (fig. 4a).

Most of the core-plug porosity values of the middle Lodgepole are only 1-2%, but increase to 4-6% near the TI-WAO target horizon (fig. 3). The higher core-plug porosities span roughly a 30-foot-thick interval, which contains 25-50% core-plug oil saturations coupled with <25% water (fig. 3). Permeability values are all ≤1 millidarcy (fig. 3), similar to the Bakken-Three Forks reservoirs. Neutron-density porosity logs indicate the middle Lodgepole is predominantly limestone in composition.

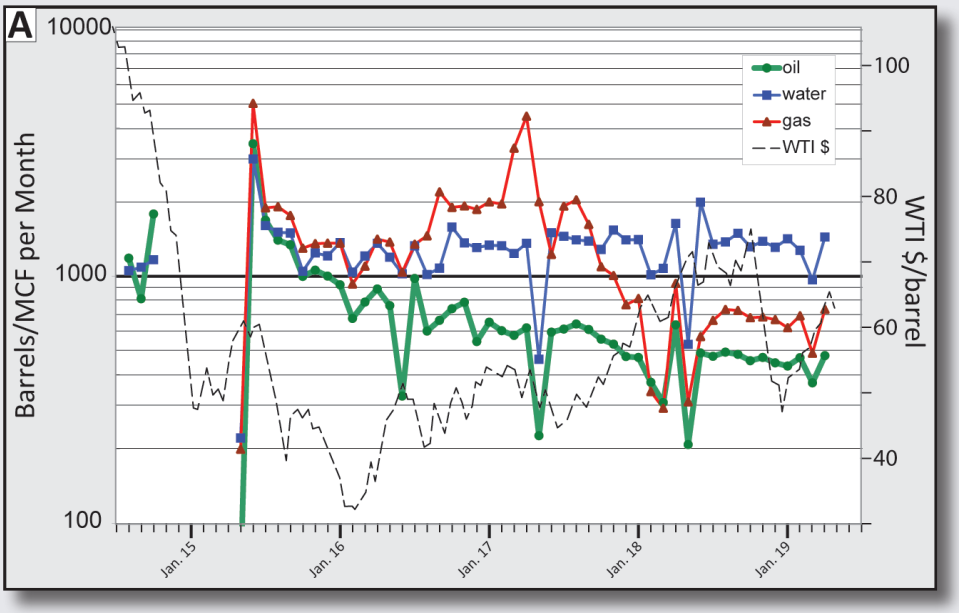
Petroleum Source for Middle Lodgepole Hydrocarbons

Originally, Bakken-generated oil was largely thought to have migrated vertically hundreds to over a thousand feet to source reservoirs of the overlying Mississippian Madison Group (Dow, 1974), and therefore would be the likely source of hydrocarbons found throughout the Lodgepole. Hydrocarbons produced from the Lodgepole mounds in the Dickinson area are understood to be locally sourced from the upper Bakken shale (Burke and Diehl, 1995), and the lower Lodgepole Scallion is considered part of the Bakken Petroleum System. However, work by Price and LeFever (1992) suggests that much of the Bakken-generated oil is still relatively in place and more recent geochemical fingerprinting studies have indicated that Madison oils are mostly distinct from Bakken oil extracts, suggesting Madison reservoirs are sourced by Madison source beds (Lillis, 2012). The False Bakken, an organic-rich shale layer, is positioned just above the Scallion of the lower Lodgepole in some areas of western North Dakota. Organic-rich samples have also been analyzed from Lodgepole carbonate beds in southern Saskatchewan with TOC values of 4-8 wt% (Osadetz and Snowdon, 1995), which classifies as excellent quality petroleum source rock (Dembicki, 2009). Therefore, Lodgepole hydrocarbons may have originated from a combination of the Bakken shales and inter-formational petroleum source beds.

Future Potential of the Middle Lodgepole

The TI-WAO was drilled and completed with only a 4,400-foot lateral and reached peak production rates of over 100 barrels of oil per day. If this well had been completed with a ~10,000-foot lateral, similar to many of the underlying the Bakken-Three Forks wells, production rates might have been doubled (fig. 4b). Furthermore, the TI-WAO was completed without any reported proppant. Adding proppant may enhance production from future completed middle Lodgepole unconventional wells. Finally, revised completion technology and/or lateral positioning may further enhance hydrocarbon production from the middle Lodgepole.

The five vertical Lodgepole wells that extend from northwestern Divide County through Williams County have also produced from the middle Lodgepole (figs. 1 and 2). Cumulative oil production from these previous vertical wells has only consisted of hundreds to several thousand barrels of oil, but their spatial distribution indicates a large area of potential for the middle Lodgepole as an unconventional target. Few studies aside from those that examine the Lodgepole mounds have looked at the Lodgepole's greater petroleum potential. Further geologic evaluation is necessary to better understand the source of middle Lodgepole hydrocarbons as well as the distribution of unconventional reservoir. Every new Bakken-Three Forks well drilled is one more opportunity to evaluate shallower prospective reservoirs, including those of the Lodgepole Formation.



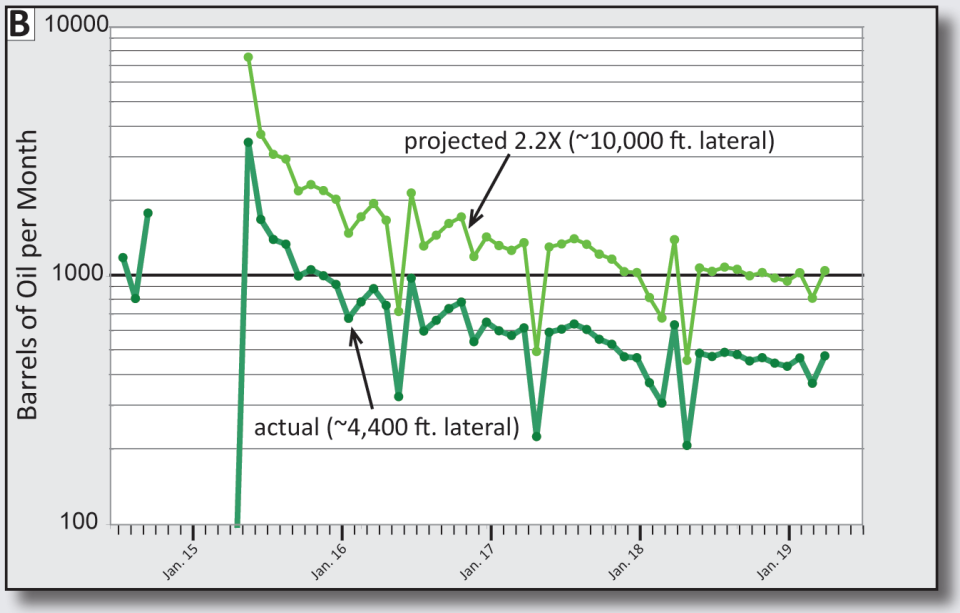


Figure 4. Monthly production diagrams for the TI-WAO-157-95-14H-1. A) Monthly oil, gas, and water production totals along with the average WTI oil price per barrel. B) Actual total monthly oil production (dark green) versus multiplied production rates (light green) as if the TI-WAO had been a ~10,000-foot-long horizontal instead of a ~4,400-foot-long horizontal well (~2.2X multiplying factor).

References

Burke, R., Diehl, P., 1993, Waulsortian Mounds and Conoco's New Lodgepole Well: North Dakota Geological Survey Newsletter, v. 22, no. 4, p. 6-17.

Burke, R., Diehl, P., 1995, The Lodgepole Formation Carbonate Buildup Play and Waulsortian Mounds in North Dakota: North Dakota Geological Survey Newsletter, v. 20, no. 2, p. 8-20.

Dembicki, H., 2009, Three common source rock evaluation errors made by geologists during prospect or play appraisals: American Association of Petroleum Geologists Bulletin, v. 93, p. 341-356.

Dow, W.G., 1974, Application of oil-correlation and source-rock data to exploration in Williston Basin: American Association of Petroleum Geologists Bulletin, v. 58, p. 1253-1262.

LeFever, J.A., 2008, Structural Contour and Isopach Maps of the Bakken Formation in North Dakota: North Dakota Geological Survey, Geological Investigations 59, 5 plates.

Lillis, P.G., 2012, Review of oil families and their petroleum systems of the Williston Basin: The Mountain Geologist, v. 50, no. 1, p. 5-31.

Mackie, J., 2013, Sedimentology and diagenesis of the lower Lodgepole Formation, Williston Basin, North Dakota: Colorado State University, Fort Collins, Colorado, MS Thesis, 113 p.

Price, L.C., and LeFever, J.A., 1992, Does Bakken horizontal drilling imply a huge oil-resource base in fractured shales?, in LeFever, J.A., eds., Geological Studies Relevant to Horizontal Drilling – Examples from Western North America: Rocky Mountain Association of Geologists, Denver, CO, p. 199-214.

Osadetz, K.G., and Snowdon, L.R., 1995, Significant Paleozoic Petroleum Source Rocks in the Canadian Williston Basin – their distribution, richness and thermal maturity (southeastern Saskatchewan and southwestern Manitoba): Geological Survey of Canada, Bulletin 487, 60 p.