Review of the Emerging Midale-Upper Rival (Mississippian Madison Group) Unconventional-Style Play, Northern Burke County

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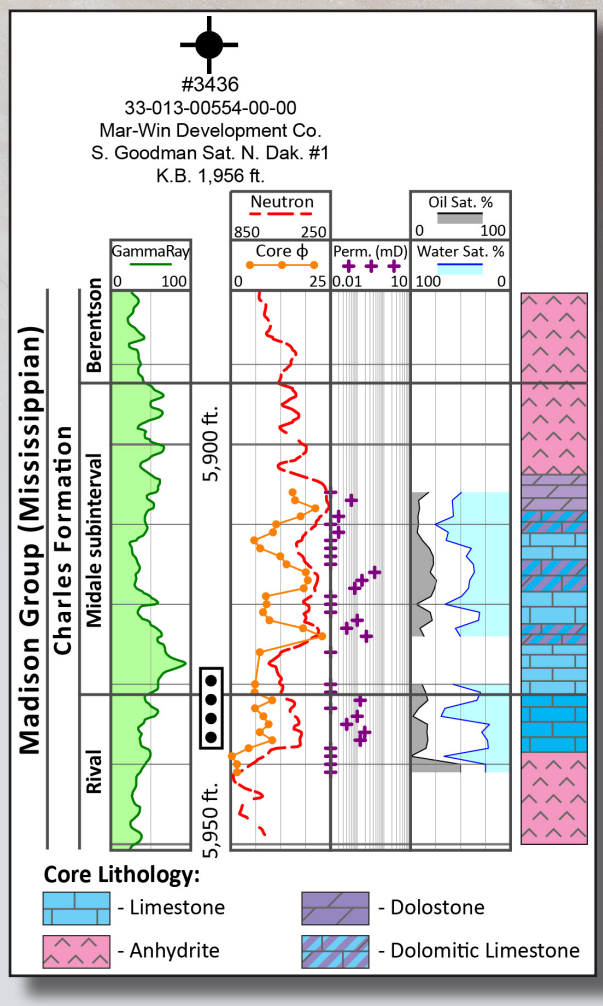

Introduction

Over two dozen horizontal wells targeting the Midale-upper Rival section of the Charles Formation (Madison Group) within northern Burke County have been completed or restimulated using multi-stage hydraulic fracturing since 2014 (figs. 1 and 2). Oil and gas production rates from these wells (reviewed below) have varied, but overall the results have been promising enough to prompt a growing number of new well permits in the area. This emerging Midale-upper Rival play appears to be the first successful augmentation of horizontal drilling and hydraulic fracturing within the Mississippian Madison Group for the North Dakota portion of the Williston Basin.

Historical Production

The Flaxton Field was discovered in 1956 with vertical exploration and development wells targeting the Midale and Rival subintervals, the basal portions of the Charles Formation (Voldseth, 1987) (figs. 1 and 2). Unitization and water flooding was attempted within several Midale-Rival oil fields proximal to the Flaxton Field, but were mostly marginally successful with the exception of the Rival Field (Lindsay, 1985). Operators later found success within the Flaxton Field area targeting slightly deeper reservoirs of the underlying Mission Canyon Formation (Voldseth, 1987). Horizontal drilling with open-hole completions began during the 1990s, which primarily targeted the uppermost part of the Rival subinterval, also referred to informally as the "Nesson," yielding varying results. A number of those early horizontal wells, however, have cumulatively produced upwards of ≥200,000 barrels of oil per well and are still actively producing.

Figure 1. Wireline logs with standard core analysis data and generalized lithologies of the Midale-upper Rival pay section in northern Burke County. Gamma ray log was deepened using wireline log from adjacent well (NDIC #10637). ϕ = core-plug porosity, perm. = permeability (millidarcies), sat. % = saturation percentage.

Recent Activity

Most recently, approximately 1- to 2-mile-long horizontal wells are being drilled targeting the Midale-upper Rival subintervals which are completed with multi-stage hydraulic fracture stimulations. There have been 13 of these Midale-Rival horizontal wells drilled and completed to date that are off confidential status* (figs. 2 and 3). Additionally, at least 10 pre-existing upper Rival horizontal wells with initial open-hole completions have been re-stimulated with multi-stage hydraulic fracturing (figs. 2 and 4). Initial production from these horizontal, hydraulically fractured wells has ranged from <50 to >400 barrels of oil per day (30-day average), which is sometimes

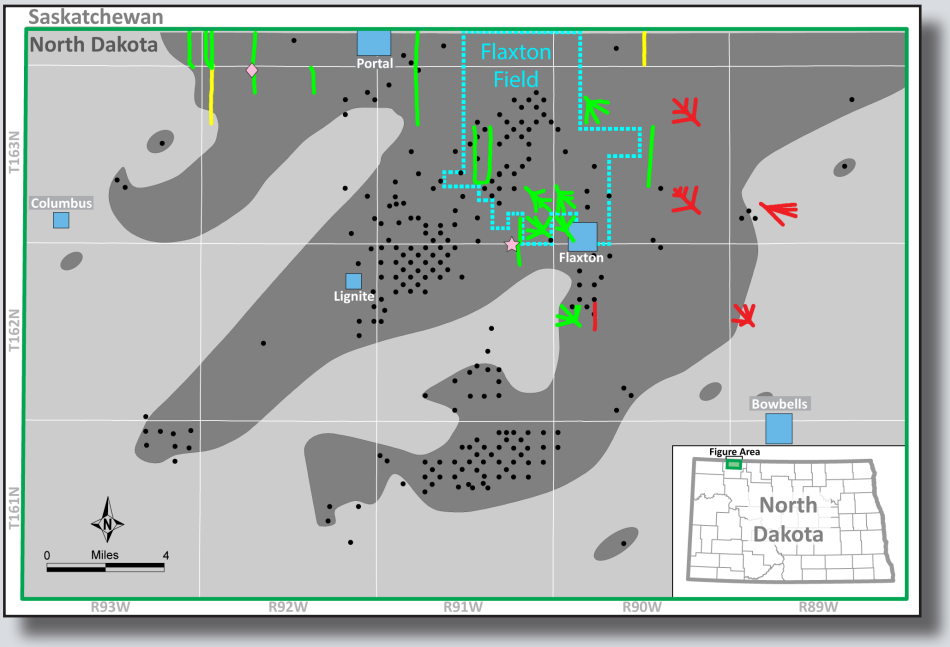

Figure 2. Midale production map for northern Burke County. Colored lines show the locations of horizontal wells drilled in the upper Rival-Midale subintervals and completed with multi-stage hydraulic fracturing. Line coloration indicates peak initial 30-day production rate averages: green = 175-400 barrels of oil per day (BOPD) for new wells and 100-165 BOPD for restimulated wells, yellow = ~125 BOPD for new wells, and red = <50 BOPD for new wells and 15-20 BOPD for restimulated wells. Black dots show the locations of vertical wells that have produced oil and gas from the Midale subinterval (many of which are commingled with the underlying upper-Rival). The darker grey area depicts the approximate extent of where the Midale contains relatively continuous oil saturations (Nesheim, 2018b). Blue squares show the locations of towns. Pink diamond = location of well #28214 (fig. 3 well). Pink star = location of well #16220 (fig. 4 well).

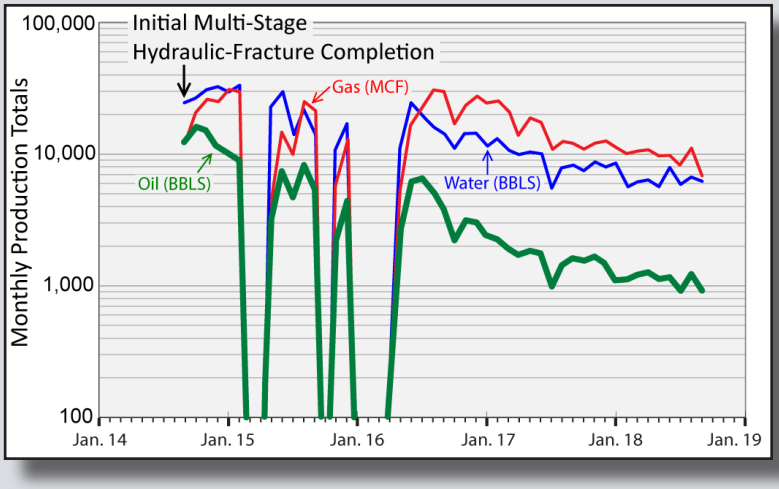

Figure 3. Monthly production diagram for Petro Harvester's Busch 32-1H (NDIC: 28214, API: 33-013-01792-00-00, Sec. 5, T163N, R92W). The Busch 32-1H is a ~one-mile lateral drilled in the Midale-upper Rival and completed with an 11-stage hydraulic fracture stimulation using 940,000 gallons of fluid and 1,181,000 lbs. of proppant. Cumulative production through August 2018 includes 174,575 BBLS oil; 690,397 BBLS water; and 591,428 MCF gas.

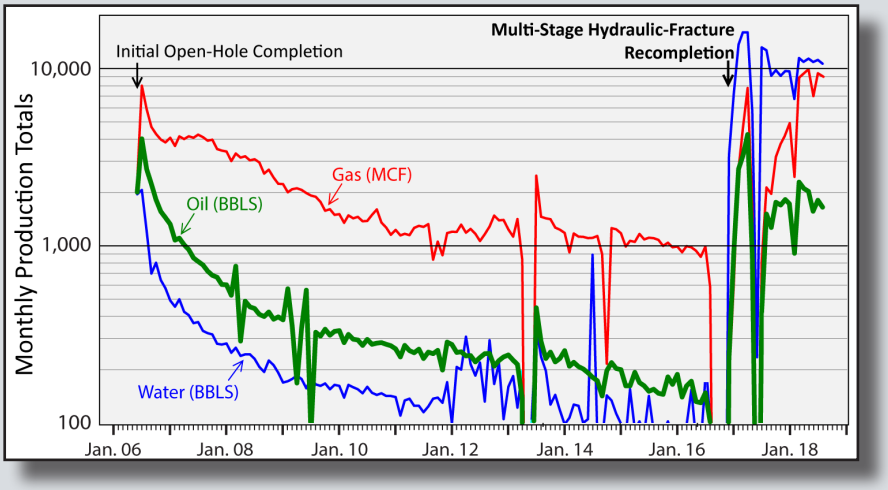

Figure 4. Monthly production diagram for Denali Oil and Gas's Nelson Unit 1 (NDIC: 16220, API: 33-013-01353-00-00, Sec. 2, T162N, R91W). The Nelson Unit 1 was drilled with two ~one-mile laterals targeting the upper Rival subinterval (Nesson). The well initially produced from open-hole completions in the laterals until being restimulated with multi-stage hydraulic fracturing in late 2016. Note the significant and sustained jump in production volumes following the restimulation.

reached during the wells' 2nd or 3rd month of production. Initial gas to oil ratio's have been around 1 MCF (thousand cubic feet) gas per barrel oil. However, the gas to oil ratio steadily climbs with continued production and often reaches 5-6 MCF/barrel of oil. Produced oil reportedly consists of light crude (39° API gravity). Water production rates are relatively high, several barrels of water are typically produced per barrel of oil. Combining both the 1-mile and 2-mile lateral wells, the 1-year (365 days) cumulative production total averages of the wells drilled and completed to date include ~54,000 barrels of oil and ~171,000 MCF gas, which has a gross value of approximately $3.7 million**.

Comparison of Midale versus Bakken-Three Forks Well Cost and Performance

Depending on lateral length and well location, operator estimated ultimate recovery (EUR) per well range from 240 to 500+ thousand barrels of oil (MBO) per well with drilling and completion costs of $2.9 to $3.8 million per well (NDIC Case No. 25307, 25982, & 26064). Comparatively, operator reported drilling-completion costs and EUR values per well across most of the Bakken-Three Forks play generally range from $6-8 million and 400-700 MBO per well. The reduced well cost for the Midale-upper Rival play is likely a combination of shallower reservoir depth (Midale = 6,000 ft. versus Bakken-Three Forks 8,000-11,000+ ft.) and a reduced number of frac stages (Midale = ~20 stages/2-mile lateral versus Bakken-Three Forks = ~40-60 stages/2-mile lateral). Both of these plays have similar economics based on operator reported values, where each $1 million of investment leads to approximately 100 MBO of resource (well EUR/drilling and completion costs).

Petroleum Geology Components

The Flaxton Field has been described as a combination structure-stratigraphic trap (Voldseth, 1987), and Madison core samples examined in the area do not appear to contain obvious petroleum source beds. Therefore, the in-place oil and gas has likely migrated from the deeper portions of the Williston Basin. The Midale-upper Rival reservoir section is both under- and overlain by thick anhydrite beds which are hydrocarbon seals that have helped trap the migrated hydrocarbons (fig. 1). Figure 2 shows the approximate area with elevated oil saturations in the Midale (oil saturation levels do vary across the indicated area based on core and log analysis data). The horizontal, hydraulically fractured wells with lower production rates all fall along or beyond the eastern margins of the oil-saturated Midale area (fig. 2).

Most of the Midale reservoir interval consists of burrowed dolomitic limestone with porosity that commonly climbs above 20% (fig. 1) (Nesheim, 2018a), which is excellent quality porosity. The underlying upper Rival is comprised of limestone (peloidal grainstone) with typically 6-12% porosity (Nesheim, 2018a). The permeability (ability of the rock to flow gas and/or fluids), however, is generally less than a millidarcy (fig. 1), which is very low for an oil-productive reservoir and a main reason for why multi-stage hydraulic fracture completions are utilized.

Future Outlook

The area of relatively continuous Midale oil saturations spans approximately 160,000 acres (fig. 2). Assuming two-mile laterals were drilled and completed across this area with one well per 320 acres (4 wells per 1280 acres), approximately 500 horizontal wells would be needed to fully develop the entire play. However, the ultimate number of horizontal Midale-upper Rivals wells will likely be less than 500 due to the following factors: the irregular shape of the oil-saturated area, reservoir depletion from legacy vertical well production, water flooding within some unitized Midale-upper Rival fields, and variable production results from unconventional-style completions. Still, the Midale-upper Rival unconventional-style play appears poised for the drilling and completion of potentially a few hundred horizontal wells, which may combine to cumulatively produce on the order of tens of millions of barrels of oil.

Across western and north-central North Dakota, over 1 billion barrels of oil have been produced from approximately 6,100 Madison wells, with productive vertical wells stretching back to the early 1950s and horizontal well drilling (non-hydraulically fractured) starting during the late 1980s to early 1990s (LeFever, 1992). As the Midale-Rival play described above continues to develop, renewed interest in the Madison Group across North Dakota's portion of the basin may follow where Madison reservoir beds are re-examined for their "unconventional" potential.

References

LeFever, J.A., 1992, Horizontal Drilling in the Williston Basin, United States and Canada: Rocky Mountain Association of Geologists, Geological Studies Relevant to Horizontal Drilling – Examples from Western North Dakota; edited by J.W. Schmoker, E.B. Coalson, and C.A. Brown, p. 177-197.

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**Oil and gas operators are allowed up to a 6 month confidentially period on new wells.*
***Assumes a wellhead price of $58.75/barrel of oil and $2.96/MCF gas, commodity prices from the October 2018 ND Director's Cut.*