Initial (60–90 Day) Average Daily Production Rates for Horizontal Wells Completed in the Bakken and Three Forks Formations, Eastern Montana

Jay A. Gunderson[1] and John M. Wunder[2]

[1] Geologist/Research Professor, Montana Bureau of Mines and Geology; [2]Geologist, Bureau of Land Management, U.S. Department of the Interior

Introduction

The Bakken–Three Forks Petroleum System in the Williston Basin is one of the most prolific continuous oil accumulations in North America, with an estimated mean of 7.4 billion barrels of technically recoverable oil resources (Gaswirth and others, 2013). Despite its designation as a "continuous" oil accumulation, horizontal wells completed in the Bakken and Three Forks Formations exhibit a wide range in productivity—both spatially and temporally.

This report summarizes the initial 60- to 90-day average daily oil, gas, and water production from each horizontal well that has produced oil from the Bakken or Three Forks Formations in eastern Montana. This provides the petroleum industry, mineral owners, the public, and Federal, State, and County land-use planners with information pertaining to historical production data from the Bakken and Three Forks Formations. Comparing initial production rates (i.e., average production rates over a specific time window after well completion) is a common and convenient way to identify "good wells" versus "poor wells." Initial production rates can also serve as a guide to identifying highly productive areas (i.e., "sweet spots") in the Montana portion of the Williston Basin and thus indicate areas where continued oil field development is likely to occur.

Geologic Background

The Williston Basin is located in parts of North Dakota, South Dakota, and Montana in the United States, and in parts of the Canadian provinces of Saskatchewan and Manitoba (fig. 1). The approximate depocenter of the basin occurs in western North Dakota, where more than 16,000 ft (4,877 m) of Phanerozoic sedimentary rocks have accumulated (Anna and others, 2013).

The Devonian–Mississippian Bakken Formation in eastern Montana occurs at approximate depths of 7,500 to 10,500 ft (2,286 to 3,200 m), and consists of the following three members in ascending order: (1) organic-rich lower shale member, (2) middle member comprising variable lithologies of dolostone, dolomitic siltstone, and sandstone, and (3) organic-rich upper shale member (fig. 2). The middle member is up to about 40 ft (12 m) thick and is the primary target for horizontal drilling in the Williston Basin. It is sourced by oil generated from both the upper and lower shale members, where these shale beds are thermally mature. The Bakken Formation unconformably overlies the Devonian Three Forks Formation, which is dominantly composed of silty dolostone, with interbeds of dolomitic mudstone and anhydrite. The upper Three Forks Formation is also a target for horizontal drilling, with oil primarily sourced from the lower Bakken shale, where thermally mature.

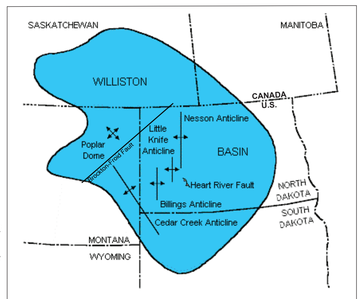

Figure 1. Approximate areal extent of the Williston Basin showing major structural elements. (Modified from NDGS website: https://www.dmr.nd.gov/ndgs/Resources/, accessed on November 1, 2018).

A primary geologic control on oil production from the Bakken and Three Forks Formations is the thermal maturity of the organic-rich upper and lower shale members of the Bakken Formation. Oil production is generally low where these shales are thermally immature and higher where the shales are thermally mature. This suggests a relatively short migration distance from the thermally mature area of the basin to where commercial accumulations of hydrocarbons are present. The areal distribution of thermally mature Bakken Formation source rock shales shown in this report in figures 3, 4, and 5 is modified from Theloy and Sonnenberg (2013), and Theloy and others (2013).

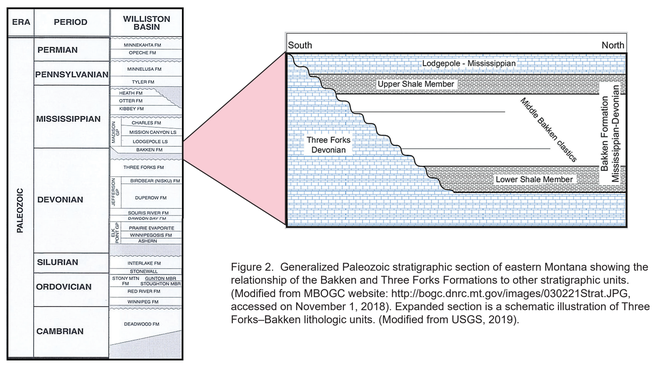

Figure 2. Generalized Paleozoic stratigraphic section of eastern Montana showing the relationship of the Bakken and Three Forks Formations to other stratigraphic units. (Modified from MBOGC website: http://bogc.dnrc.mt.gov/images/030221Strat.JPG, accessed on November 1, 2018). Expanded section is a schematic illustration of Three Forks–Bakken lithologic units. (Modified from USGS, 2019).

The first oil production in eastern Montana from the Bakken or Three Forks Formations was from the Harold Joyes 1 well (API No. 25-091-21106), completed on August 31, 1970, in Sheridan County. The first horizontal well in eastern Montana to produce oil from the Bakken or Three Forks Formations was the Strand 22-27H well (API No. 25-083-21779), completed on June 11, 1989, in Richland County. During the next 18 months, two additional horizontal wells were drilled into the Bakken Formation in Richland County. Each had an initial average daily production rate under 16 barrels of oil per day. A decade later, development of Elm Coulee field was initiated when the Burning Tree-State 36-2H horizontal well (API No. 25-083-21881) was drilled and completed with an average daily production rate of over 100 barrels of oil per day from the Bakken Formation. Since 2000, approximately 214 million barrels of oil have been produced from horizontal wells completed in the Bakken Formation in eastern Montana, with another 1.5 million barrels produced from the Three Forks Formation.

Methods

For this study, we used oil, gas, and water production data from the initial 60 to 90 days of oil production from horizontal wells completed in the Bakken or Three Forks Formation in eastern Montana. Well production data were obtained from the Montana Board of Oil and Gas Conservation (MBOGC). The 1,238 wells used in this study were drilled between 2000 and 2018 and have at least 60 days of reported oil production as of October 31, 2018. We used data from only horizontal wells because production data from vertical wells that pre-date modern drilling and completion methods could skew the data and potentially give misleading results. No attempt was made to normalize production data based upon horizontal wellbore length, wellbore orientation relative to the regional fracture pattern, proximity to existing wells, choke size, number of fracture stages, type and pounds of proppant used in the fracture stimulation treatment, or other differences in well completion methods. All are likely to impact production rates, but accounting for these differences on a well-by-well basis is difficult and time-consuming, and beyond the scope of this report.

Production volumes for each well are reported to the MBOGC on a monthly basis rather than a daily basis. The number of days a well is "on production" during each month is also reported. Using both the monthly production volumes and the number of days on production, we computed the "first 60- to 90-day average daily production" rate for each well by averaging the daily production over *at least* the first 60 days, and *no more* than the first 90 days the well was on production. Thus, the results shown do **not** represent the average daily production within the 60–90 day "window," but instead show the average daily production during the initial 60 to 90 days of oil production. The 60- to 90-day average daily production data used in this study are available for download from the MBMG website.

The decision to analyze production data during the initial 60 to 90 days of oil production from a well was to allow time for the flowback of fluids that were injected into the reservoir during fracture stimulation treatment to "cleanup" each well for at least 60 days. Some flowback of injected fluids may still occur in some wells after the initial 60 days of oil production; however, the authors believe a 60-day cleanup period is reasonable to obtain reliable and meaningful results for the purpose of this study. Furthermore, using the initial 60 to 90 days of oil production allows for broad comparison to a similar study involving the first 60 to 90 days of oil production from the Bakken Pool conducted by Nordeng (2010) in the North Dakota part of the Williston Basin.

Results

The results of our analyses of the initial 60 to 90 days of oil, gas, and water production from each horizontal well producing oil from the Bakken and Three Forks Formations in eastern Montana are shown in various figures and charts. For simplicity, the term "initial" production in the following discussion refers to the "first 60-to 90-day average daily" production as described above.

Figures 3, 4, and 5 are bubble maps showing the first 60- to 90-day average daily (initial) rates of oil production, gas production, and the average gas–oil ratio for horizontal wells producing from the Bakken and Three Forks Formations in eastern Montana. For continuity, we used similar scales, colors, and data classifications as Nordeng's (2010) map for North Dakota. The MBOGC's three field designations for wells producing from the Bakken or Three Forks Formations are Elm Coulee, Elm Coulee Northeast, and Flat Lake. The boundaries of Elm Coulee field are shown in figures 3, 4, and 5. The Elm Coulee Northeast field includes all wells outside of Elm Coulee field, with the exception of about 30 wells in the far northeast corner of Montana assigned to Flat Lake field.

The distribution of initial oil production rates for all 1,238 horizontal wells used in this study is shown in figure 6; the median initial oil production rate from these wells is 215 barrels/day. Figure 7 shows the change in initial oil production rates over time for wells drilled in Elm Coulee and Elm Coulee Northeast fields. The initial production rates of several recent Elm Coulee Northeast wells exceed the initial production rates of earlier wells drilled in either field, and may be the result of improved drilling and completion methods.

A map of "water cut" [barrels water / (barrels water + barrels oil)] based on the initial production rates from each well shows distinct differences in relative oil–water production between wells drilled in Elm Coulee field and wells drilled to the northeast (fig. 8). This supports the widely held view of Elm Coulee as a "sweet spot" in the Montana portion of the Williston Basin. The reason(s) for this phenomenon is beyond the scope of this study; however, it may be due to relatively high matrix porosity, low water saturation and/or, in the absence of a traditional oil–water contact, a difference in wettability of the reservoir.

Maps may be obtained from:
Publications Office
Montana Bureau of Mines and Geology
1300 West Park Street
Butte, Montana 59701-8997
Phone: (406) 496-4174
http://mbmg.mtech.edu

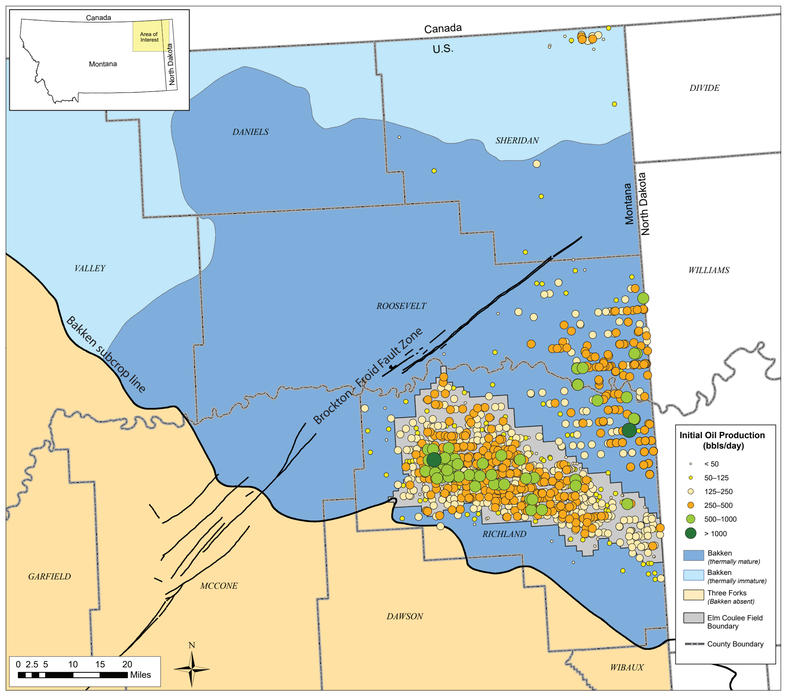

Figure 3. Initial 60- to 90-day average daily oil production in barrels per day (bbls/day).

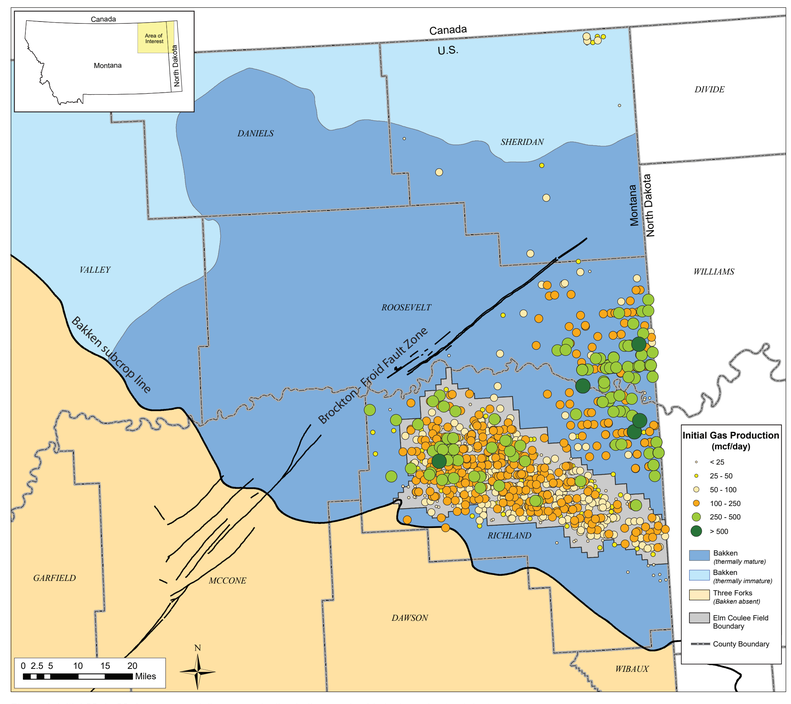

Figure 4. Initial 60- to 90-day average daily gas production in thousand cubic feet per day (mcf/day).

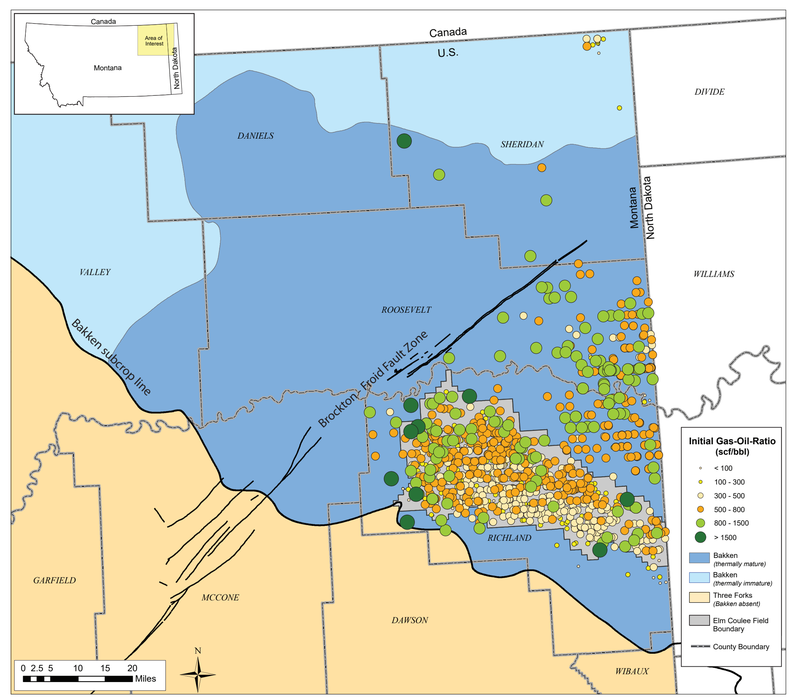

Figure 5. Initial 60- to 90-day average gas-oil ratio computed as standard cubic feet of gas per barrel of oil (scf/bbl).

References Cited

Anna, L.O., Pollastro, R., and Gaswirth, S.B., 2013, Williston Basin Province—Stratigraphic and structural framework to a geologic assessment of undiscovered oil and gas resources, *in* U.S. Geological Survey Williston Basin Province Assessment Team, Assessment of undiscovered oil and gas resources of the Williston Basin Province of North Dakota, Montana, and South Dakota, 2010: U.S. Geological Survey Digital Data Series 69–W, Ch. 2, 17 p., https://pubs.usgs.gov/dds/dds-069/dds-069-w/ [Accessed 6/19/2013].

Gaswirth, S.B., Marra, K.R., Cook, T.A., Charpentier, R.R., Gautier, D.L., Higley, D.K., Klett, T.R., Lewan, M.D., Lillis, P.G., Schenk, C.J., Tennyson, M.E., and Whidden, K.J., 2013, Assessment of undiscovered oil resources in the Bakken and Three Forks Formations, Williston Basin Province, Montana, North Dakota, and South Dakota, 2013: U.S. Geological Survey Fact Sheet 2013–3013, 4 p., https://pubs.usgs.gov/fs/2013/3013/ [Accessed 6/19/2013].

MBOGC, 2019, http://www.bogc.dnrc.mt.gov/WebApps/DataMiner/ [Accessed 11/28/2018].

Nordeng, S.H., 2010, First 60–90 day average Bakken Pool production by well: North Dakota Geological Survey Geologic Investigation 123, 1 pl.

Theloy, C., and Sonnenberg, S.A., 2013, Integrating geology and engineering—Implications for production in the Bakken Play, Williston Basin: Unconventional Resources Technology Conference, Denver, Colorado, August 12–14, 2013, Paper 1596247, 12 p.

Theloy, C., Sonnenberg, S.A., and Jin, H., 2013, Integration of geological and technological aspects and their influence on production in the Bakken play, Williston Basin: PowerPoint presentation given at the Williston Basin Petroleum Conference, Regina, SK, May 2, 2013, 26 p.

USGS, 2019, http://energy.usgs.gov/Portals/0/Rooms/oil_and_gas/noga/multimedia/2013_Bakken_ThreeForks_Assessment.pdf [Accessed 11/1/2018].

Acknowledgments

The authors thank Jim Halvorson of the Montana Board of Oil and Gas, Todd Hoffman of Montana Tech, and Katie McDonald of the Montana Bureau of Mines and Geology for their technical review of this report and for providing helpful comments and suggestions. Simon Bierbach and Susan Smith of the Montana Bureau of Mines and Geology assisted with the graphics and layout. Edited by Susan Barth, MBMG.

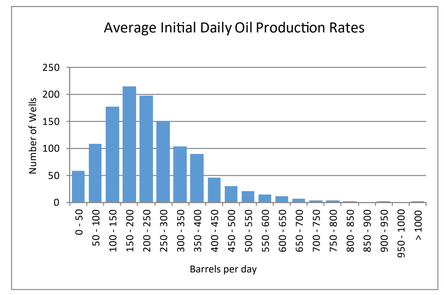

Figure 6. Average initial daily oil production for horizontal Bakken and Three Forks Formations wells (median = 215 barrels per day).

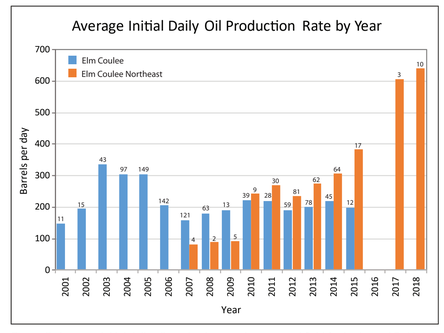

Figure 7. Average initial daily oil production rate by year and field for horizontal Bakken and Three Forks Formations wells. The number of wells is displayed above each vertical bar.

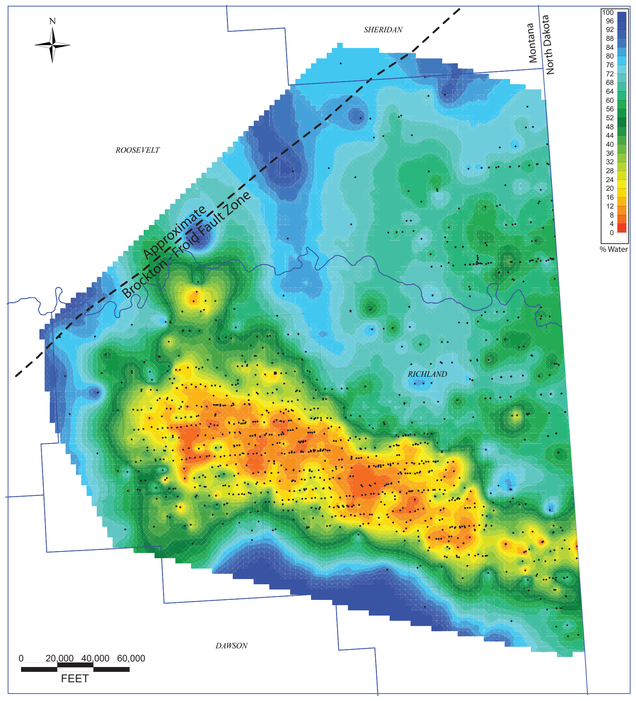

Figure 8. Percent water production from initial 60- to 90-day production rates.