GEOLOGIC REPORT ON THE BAKKEN FORMATION IN THE VICINITY OF SPRING LAKE FIELD RICHLAND COUNTY, MONTANA

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Introduction

The Spring Lake Bakken study area is in the central part of Richland County, Montana, on the southwest side of the Williston Basin (Figure 1). It includes all of Tps. 23, 24, and 25 N., Rgs. 54 and 55 E. (Plates 1, 2, and 3). Because of a 2-mile offset in the land survey grid, it also includes the western one-third of Tps. 23 and 24 N., R. 56 E. and the eastern one-third of T. 25 N., R. 53 E., Montana Principal Meridian. This study was originally conducted as part of the U.S. Bureau of Land Management's Known Geologic Structure (KGS) program. It also includes several fields that did not affect federal minerals. The study was completed in 1987 and subsequently does not include information from recent horizontal drilling taking place in the area. Seven Bakken producers are scattered throughout the 200+ square mile study area and were completed as salvage for unsuccessful or depleted deeper zone tests. All of these Bakken salvage completions were successful. There have been no dry or water bearing wells.

History of Production

There are seven wells in this study area which have been completed for production in the Bakken Formation. This production is in the Two Waters-North Enid Fields in T. 24 N., R. 54 E., the Girard Field in T. 24 N., R. 55 E., and the Spring Lake-West Spring Lake Fields in T. 25 N., R. 54 E. (Plates 1, 2, and 3). Cumulative production through May 1987 is 204,715 barrels of oil (BO), 129,963 thousand cubic feet (MCF) gas, and 6,171 barrels of water (BW). Average gas-oil ratio (GOR) is 634:1.

The North Enid Field had the first Bakken discovery well in the study area. It is the Duffield l BN (drilled and completed as the Coastal l Hatley), NENWSE, sec. 33, T. 24 N., R. 54 E. It produced from June 198l to August 1986. It found the Bakken middle member to be fractured with 4 percent porosity and 5 percent water saturation (using a resistivity for water (RW) of .018). The upper Bakken shale was also fractured. An attempted drillstem test (DST) was a misrun. Perforations started in the lower Lodgepole covered all of the upper Bakken shale and the upper 13 feet of the middle Bakken. A 3,000-gallon acid job was followed by a sand-oil frac using 45,000 gallons crude oil and 40,000 pounds of sand. Initial potential (IP) was flowing 90 BO, 123 MCF, 2 BWPD with 100 pounds flowing tubing pressure. The oil was 47o gravity. It had a cumulative production of 40,243 BO; 50,757 MCF; 1251 BW over a 5-year and 2-month life. Gas-oil ratio was 664:1. As of January 1988, it was inactive awaiting a decision to plug and abandon. In the first 2 years, it had produced about 35,000 barrels or 7/8 of

this total. From August 1984 through August 1986 its monthly production was 0 to 3 BOPD. This well has apparently never been on pump, although this assumption could be due to incomplete data. A computer-projected decline curve indicates that its recoverable reserves were 39,729 BO.

The best Bakken well in this study area was completed in April 1982 in Spring Lake Field (Figure 2). The Torch 9-27 BN-Strand (originally drilled by Merland and completed by Flare) found the middle Bakken to be 38 feet thick, of which 12 feet appear to be fractured. Porosity is 8 percent and the water saturation is 18 percent (using .018 RW). The upper Bakken shale is also fractured. A DST recovered 180 feet of highly gas-cut mud. The shut-in pressure rose from 4,511 to 4,633 pounds. To insure a good cement job across the pay, the operator perforated above and below the pay and "cement squeezed". The upper 14 feet of the middle Bakken was then perforated and fractured with 57,372 gallons of diesel and 120,000 pounds of sand. Initial potential was flowing 90 BOPD. Cumulative production through May 1987 is 66,786 BO, 36,732 MCF, 470 BW over its 5ðyear life. Gas-oil ratio is 520:1. It has been on pump for several years and is still producing 35 to 40 BPD of 42o gravity oil. The computer decline curve projects to a life of 24 years and recoverable reserves of 293,364 BO.

Shortly after Flare had completed the Spring Lake Bakken discovery, Hunt Oil Co. completed l Hull as a northeast 160-acre offset to the North Enid Bakken discovery of Coastal. The location is NESWNW, sec. 34, T. 24 N., R. 54 E. Hunt perforated the entire middle Bakken member, which is 22 feet thick. Porosity is 5 percent, and water saturation is 5 percent. They sand-oil fractured with 42,410 gallons diesel and 50,000 pounds sand. It initialed at pumping 75 BO; 732 MCFGPD. A year later, it declined to 10 to 15 BOPD. Cumulative is 17,397 BO, 12,528 MCFG, 1,627 BW. Gas-oil ratio is 720:1. The well was plugged and abandoned (P&A) in 1986. The decline curve indicates recoverable reserves of 27,418 BO.

In July 1982, two more Bakken discoveries were added. Hunt completed the Apache 16-3 state in the Two Waters area pumping 35 BO; 30 MCF and 6 BWPD, located in the NW , sec. 16, T. 24 N., R. 54 E. Bow Valley recompleted a Silurian well to Bakken in the Girard Field located SE NW NW , sec. 12, T. 24 N., R. 55 E., flowing 84 BOPD. Both wells were sand-oil fractured, and each is now producing about 9 BOPD with a cumulative of about 21,000 BO. The Hunt well GOR is 914:l. The Bow Valley well apparently has a low GOR and has not been reporting gas production. These wells should produce 40,000 to 75,000 barrels each.

No further Bakken activity occurred in the study area for 3 years. Then in June l985, Kaneb re-entered the Mosbacher 29-1 Pruett-BN in the NE, sec. 29, T. 24 N., R. 54 E., which had been completed in 1981 in the Devonian Duperow. The middle Bakken was perforated and fractured. Initial potential was pumping 65 BO and 30 MCFGPD. Porosity is 7 percent, and water saturation is 4 percent.

Cumulative is 18,101 BO, 8 MCFG, 342 BW; GOR is 0.5:1. In May 1987, it was averaging 26 BOPD, indicating that it should have recoverable reserves of about 120,000 BO.

The last Bakken completion to date is the Cenex 16ð33 Strand-Gunderson. Originally, this well in the SE , sec. 33, T. 25 N., R. 54 E., was completed in 1980 as a Duperow producer. In July 1985, it was recompleted in the Bakken pumping 59 BOPD. Perforations included 6 feet of Lower Lodgepole, all of the upper Bakken shale, and 18 feet of the middle Bakken. A sand-oil frac was done. Porosity is 8 percent, and water saturation is 15 percent. Fractures are indicated in the middle Bakken and in the upper Bakken shale. Cumulative production through May 1987 is 19,314 BO, 9,435 MCF, and 589 BW. GOR is 488:1. At last report, the producing average was 23 BO; 14 MCFG; BWPD, GOR is 609:1. Recoverable reserves of 125,993 barrels are indicated.

An attempt to recomplete two dry holes in sec. 12, T. 24 N., R. 54 E., has been abandoned. Both wells appear to have fractures in the middle Bakken and the upper Bakken shale. They have log calculated water saturations of less than 20 percent and porosity of 8 to 9 percent. Kaneb re-entered the well in the NE (Figure 3) and found junk in the hole at 4,189 feet, where upon they abandoned the well.

Geology of the Producing Horizon

Stratigraphy - The Devonian-Mississippian Bakken Formation consists of an upper and a lower shale which are black, organic rich, and highly radio active. Both shale members are easily identified by high, off-scale gamma ray readings. The middle member is primarily a dolomite which is sometimes silty in this study area. This three-part sequence is generally transgressive with the depositional pinchout of the middle member occurring about 13 miles south-southwest of the lower shale pinchout (Plates 2 and 3). In this area, the lower shale limits trend east-west through the middle of T. 25 N. The middle member pinchout trends west-northwest to eastðsoutheast along the southern edge of the study area. The upper shale pinchout occurs south of (and outside) the study area. The actual Mississippian-Devonion (Figures 2 and 3) contact has been placed in the lower part of the middle member based on macrofossils (Thrasher, 1985). This lower part of the middle member is apparently the only portion of the Bakken deposited in a regressing sea. It and the underlying Three Forks Formation are not involved in any production in this study area. Likewise, the lower Lodgepole limestone and "False Bakken" (Carrington shale?), above the upper Bakken, are not involved in Bakken production in this area.

Structure - Structural strike is north-south (Plate 1). Regional dip is eastward at about 50 feet per mile. It is steeper in the northwestern portion (50 to 80 feet per mile) and shallower in the southeastern portion (25 to 45 feet per mile). The individual structures exhibit only 20 to 50 feet of critical closure. These structures

appear to trend either north-south (Stampede-E. Charlie Creek) or east-west (Spring Lake-Girard). There are at least 15 and possibly as many as 25 individual closures in this study area.

Geologic Elements Which Limit Production

Within the study area, the presence of fractures is considered the most important element of determining potential production (Plate 3). The use of fractures as a reservoir characteristic is based on the observation that every Bakken completion was from a well that shows electric log evidence of having natural fractures. There are no completion attempts in wells that appear unfractured. Their presence is indicated by the letter "F" next to the well symbol. Their absence is indicated by the letters "NF" next to the well symbol. Fractures were identified on the Dual Laterolog (DLL)-Micospherically Focused Log (MSFL) by separations between the deep laterolog and the MSFL (Figures 2 and 3). This separation occurs due to filtrate invasion into the fracture system and/or formation porosity. Of the 81 wells drilled through the Bakken, in this area, there were 68 which ran the modern log suite suitable for this determination. These fractures are apparently closed or the porosity so low that no contribution to production is possible unit subjected to a large fracturing stimulation.

Drill stem tests of the Bakken do not yield any free formation fluid (water or oil) in this area. The lone exception was in sec. 22, T.24 N., R. 54E. In 2 hours of total open time this well yielded 228 feet of slightly oil and heavily gas cut mud. The sample chamber contained 60 cc oil, 1020 cc mud, and 86 cubic feet of gas.

It therefore appears that the reservoir is created by the fracture stimulation and is limited by the extent of such stimulation. Acres drained and drainage radius were then calculated for each of the seven Bakken completions utilizing their individual production decline curves to ascertain the recoverable reserves of each. The drainage radius for each producer was plotted on the map and assumed to represent the extent of the reservoir. None affected federal minerals. Therefore, a KGS determination was not needed.

Compared to the Bakken study areas in North Dakota (Hansen, 1986a, 1986b, Lowry and Lane, 1985), this area is sparsely drilled, contains a very small number of Bakken completions, and has very little federal acreage.

Conclusion

This study area is at the northwest limits of Bakken production in Montana to date. It is anticipated that future drilling will extend Bakken production northwestward at least a township and probably more. East and southeast of this study area, for a distance of about 25 miles to the North Dakota State line, there are a few scattered Bakken producers. Future studies may extend the oil trapping parameters of this study into that area.

All Bakken producers in this study are in the 9,600 to 10,000 foot depth range. The General Rules and Regulations of the State of Montana specify 160-acre spacing for these depths. No spacing unit containing federal minerals intersected the reservoir limits as defined in the previous section.

At this point, it appears that the IP is controlled by the stimulation technique and cannot be inferred from electric log parameters. It also appears to be the only parameter that is directly related to recoverable reserves and drainage radius. Since the drainage radii of the seven existing wells do not affect federal minerals, forming a KGS was deemed unwarranted at the time this report was completed.

/References

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