Exploration and Development of the Winnipeg/Deadwood Deep Gas Play along the Nesson Anticline

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Introduction

In the early 1990s, Amerada Hess Corporation began completing a series of deep gas wells in the Black Island (Winnipeg Group) and upper Deadwood Formations along the Nesson and Antelope Anticlines (fig. 1). Primarily targeting sandstone intervals within the upper Black Island Formation (fig. 2), 13 deep gas wells have been completed in the Winnipeg/Deadwood along the Nesson and Antelope Anticlines to date, 12 by Amerada Hess Corporation (now Hess Corporation). With individual well production totals ranging from just 2,073 barrels of oil equivalent (BOE) to over 3.5 million BOE (~20 billion cubic feet, BCF dry gas), these 13 wells have cumulatively produced over 16 million BOE of dry gas (Nesheim, 2012). Peak production took place in April of 1997 when over 145,000 BOE (~0.8 BCF gas) were produced from the Winnipeg/Deadwood system (fig. 3). With most of Amerada Hess's deep gas wells completed in the middle 1990s, their success was partly overshadowed by the developing horizontal fractured Bakken upper shale play, the discovery and exploration of the prolific Lodgepole mounds, and the Red River Horizontal B discovery.

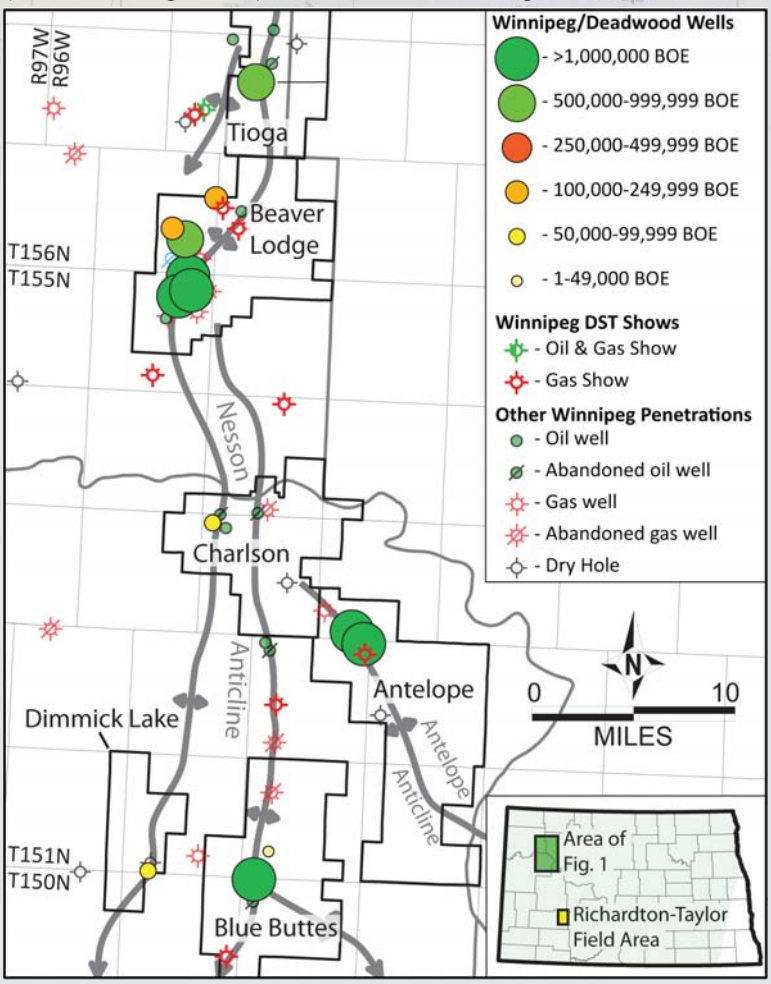

Figure 1. Field map of the central Nesson and Antelope Anticlines area. Colored circles depict productive Winnipeg/Deadwood completions sized and color coded to cumulative production through August 2012.

Geology

The Black Island Formation is made up of two members (fig. 2). The Hawkeye Valley Member (lower Black Island) consists primarily of redbeds, varying from shale to sandstone, deposited in a fluvial/deltaic setting (Ellingson and LeFever, 1995). The Garland Member (upper Black Island) is made up mostly of bioturbated shaly to silty sandstones interbedded with massive to cross-bedded mature sandstones (quartz arenite) deposited during the beginning of a Middle Ordovician marine transgression (Ellingson and LeFever, 1995). The Black Island Formation was deposited unconformably over the eroded Cambrian-Ordovician Deadwood Formation surface (fig. 2). The Black Island Formation is conformably overlain by the Icebox Formation, which was deposited in a deeper marine environment and consists primarily of shale. The Icebox Formation likely serves both as the source rock and the seal for the Black Island reservoir.

Overview of Early Winnipeg/Black Island Exploration and Success

Amerada Petroleum Corporation began exploring the Winnipeg's hydrocarbon potential in the late 1950s by drilling several test wells in the Beaver Lodge and Antelope Fields (fig. 1) (Anderson, 1982). Two of Amerada's Winnipeg test wells from the Beaver Lodge Field flowed 3,160 thousand cubic feet of gas per day (MCFGPD) and 8,169 MCFGPD with 18 barrels of condensate per day (BCPD). While both wells were plugged back and completed in shallower horizons, one was eventually recompleted as the first Winnipeg sand (Black Island Fm.) producer in the basin. The Iverson-Nelson Unit

Comparing Oil and Gas Production

There are two ways of comparing natural gas to oil, energy equivalence and economic equivalence. Energy wise, 5.6 MCF of natural gas (methane) is roughly equivalent to 1 barrel of oil. So in energy equivalence, 3,000 MCF gas = ~530 BBLS oil and 1 BCF (billion cubic feet) = ~178,000 BBLS oil. However, as of February 2013, natural gas in the Williston Basin sold for $3.69/MCF whereas oil sold for $84.75/barrel of oil, approximately a 23 to 1 ratio (MCF:BBLS). So economically, 3,000 MCF natural gas = ~130 BBLS oil, and 1 BCF = ~44,000 BBLS oil. While the economic ratio of gas to oil changes, the energy ratio remains constant.

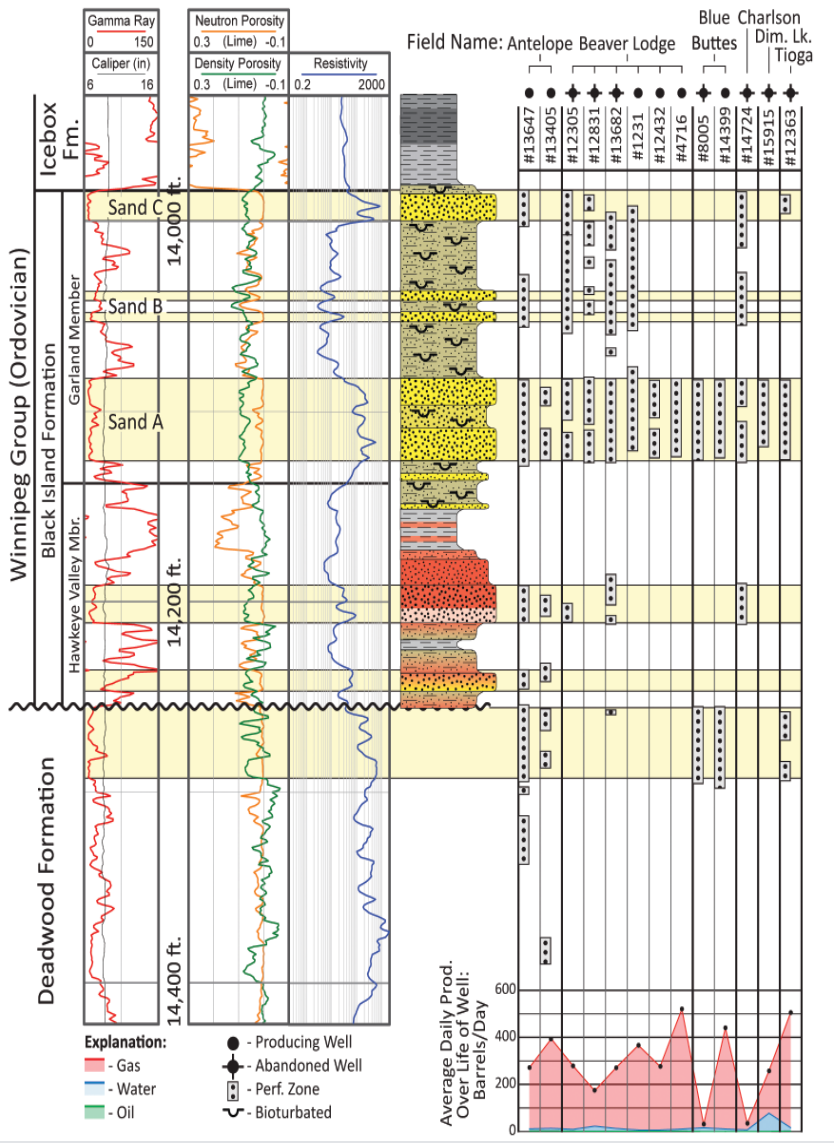

Figure 2. Composite type log and illustrated core of the Black Island Formation along the Nesson and Antelope Anticlines with individual well perforation intervals depicted on the right hand side. Gas production was converted to BOE assuming 5.62 MCF gas = 1 barrel of oil.

NDIC	Township and Range
1231	SE¼ NE¼ Sec. 2, T155N, R96W
4716	NW¼ Sec. 11, T155N, R96W
8088	NW¼ NE¼ Sec. 28, T141N, R93W
8169	NE¼ NW¼ Sec. 21, T138N, R92W
9056	SE¼ NW¼ Sec. 24, T139N, R93W
12305	NE¼ NE¼ Sec. 13, T156N, R96W
12432	SE¼ SE¼ Sec. 2, T155N, R96W
12831	SE¼ SE¼ Sec. 22, T156N, R96W
13405	NE¼ Sec. 1, T152N, R95W
13647	NE¼ SE¼ Sec. 32, T153N, R94W
13682	SE¼ NW¼ Sec. 26, T156N, R96W
14399	SW¼ NE¼, Sec. 6, T150N, R95W
15915	SE¼ SW¼ Sec. 32, T151N, R96W
21235	SW¼ SW¼ Sec. 4, T140N, R93W

Table 1. Township and Range locations with NDIC numbers for Winnipeg productive wells referred to within text.

#1 (NDIC 1231, see Table 1 for location) was recompleted in 1963 as a comingled producer with perforations in both the Red River and Black Island horizons. During this time Texaco also drilled and tested the Winnipeg in the Blue Buttes and Charlson Fields (fig. 1) with reported gas flows (Anderson, 1982).

During the late 1960s through the early 1980s, several wells drilled in eastern Montana reported Winnipeg gas recoveries, demonstrating Winnipeg gas presence away from the Nesson Anticline, but did not yield any economic production (Anderson, 1982). Then, in early 1981, Gulf Oil's 1-21-1B Leviathan (NDIC 8169) and Mobil's 1 Bernhardt (NDIC 8088) drilled along the Heart River Fault in eastern Stark County tested the Winnipeg for 3,230 MCFGPD with 1.5 BCPD and 2,100 MCFGPD (Richardton-Taylor Field Area – fig. 1). While the Leviathan went onto be a successful completion, producing for about eight years, the Bernhardt's Winnipeg completion was unsuccessful – possibly because treatment procedures damaged the reservoir (Anderson, 1982). Later that same year Gulf Oil drilled and completed the Ogre #1-24-1C (NDIC 9056), also in eastern Stark County, in the upper Black Island with an initial production (IP) of 120 BCPD and 3,230 MCFGPD with no reported water. Both of the Gulf Oil discoveries were drilled primarily on regional and detailed seismic mapping. However, contrary to the belief they were playing a stratigraphic trap, step-out development wells drilled by Gulf Oil along the Heart River Fault were unable to establish commercial production due to overall poor reservoir quality (Chimney et al., 1992), and more than ten years passed before the next Winnipeg discovery.

Amerada Hess Corporation's Deep Winnipeg/Deadwood Gas Play

After several promising production tests stretching back to 1956, and one successful comingled Winnipeg-Red River completion in 1963, the Winnipeg/Deadwood deep gas play first began to develop in the early 1990s. Beginning in the Beaver Lodge Field along the Nesson Anticline (fig. 1), Amerada Hess recompleted three wells in the Black Island Formation during 1992. These wells included the Beaver Lodge-Silurian Unit #D-407 (NDIC 12432), the Iverson-Nelson U. #1 (NDIC 1231), and the Beaver Lodge-Ordovician Unit #4 (NDIC 4716). All three of these recompletions initially produced 4,000-6,000 MCFGPD with no more than 10 BWPD and 1-3 BCPD over their first year of production. Perforations

Abbreviations

BBLS = barrels, BCF = billion cubic feet of gas, BCPD = barrels of condensate per day, BOE = barrels of oil equivalent (energy equivalent), BWPD = barrels of water per day, IP = initial production, MCF = thousand cubic feet of gas, MCFGPD = thousand cubic feet of gas per day, mD = millidarcies, NDIC = North Dakota Industrial Commission.

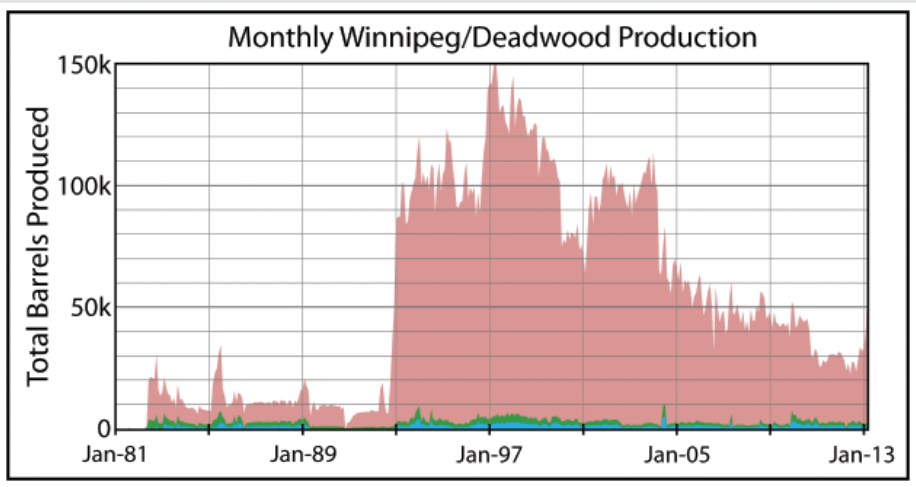

Figure 3. Monthly production history of the Winnipeg/Deadwood with gas converted to BOE. Production data does not include the Newporte Field from north-central North Dakota because of its localized nature. Red = barrels of oil equivalent gas, green = barrels of oil, blue = barrels of water.

extended from the middle to upper portions of the Black Island Formation (fig. 2).

Following their successful Black Island recompletions, Amerada Hess went on to complete three more Black Island gas wells in the Beaver Lodge Field during the middle 1990s. The Nelson #22-44 (NDIC 12831), originally a Red River producer, recompleted with an IP of 2,492 MCFGPD, 41 BWPD, and 1 BCPD in 1993. The following year the Beaver Lodge-Ordovician Unit #10 (NDIC 13682) was spudded and completed in the Black Island/upper Deadwood with an IP of 3,930 MCFGPD, 4 BWPD, and 2 BCPD. Lastly, the Nels Anderson #1 (NDIC 12305) recompleted in the Black Island during 1996 with an IP of 3,893 MCFGPD and 15 BWPD. Winnipeg/Deadwood completions in the Beaver Lodge Field have produced over 31,000 BBLS oil, 118,000 BBLS water, and 55 BCF gas with two wells still currently producing.

Amerada Hess Corporation completed an additional six Winnipeg/Deadwood deep gas wells along the Nesson and Antelope Anticlines within the following fields: Antelope, Blue Buttes, Charlson, and Tioga (fig. 1). Four of these wells have each produced over 8 BCF of gas (the uneconomic wells each produce less than 0.5 BCF gas). Based on initial production tests, the economic wells from Antelope Field (Brenna-Lacey 1 #32, NDIC 13405, and Oscar Moe, NDIC 13647) and Blue Buttes Field (Lovaas #6-32, NDIC 14399) produce at least 70% of their dry gas from upper Deadwood perforations. The uneconomic producers, as well as other completion attempts throughout the Nesson Anticline area, also yielded hydrocarbons with limited water, but failed due to uneconomic flow rates.

The most recent Winnipeg/Deadwood completion to produce along the Nesson Anticline (completed on November 21, 2006) was Houston Exploration's Fancy Butte 14-32 (NDIC 15915), which has been the only Winnipeg/Deadwood producer along the Nesson Anticline not completed by Amerada Hess. With a good IP of 4,200 MCFGPD, the Fancy Butte averaged about 40,000 MCF per month over its first four months of production. However, production rates then dropped off and after 3 or so years of minimal gas production the well was abandoned.

Within the last couple years, BTA Oil Producers drilled the Sharon #1 (NDIC: 21235), a Winnipeg (Black Island Fm.) gas discovery in northeastern Stark County (Richardton-Taylor Field Area – fig. 1). Drilled along the Heart River Fault trend, the Sharon #1 followed a similar exploration method to the Amerada Hess wells further north in that the Sharon #1 was drilled on a structural high identified by 3-D seismic. The Sharon #1 was completed in the Black Island Formation yielding an IP of 5,011 MCFGPD with no reported oil or water. After several inactive months awaiting pipeline completion, the Sharon #1 is currently producing approximately 4,000 MCFGPD with 7 BCPD and 8 BWPD.

Exploration Methods

Drilling and completion results in combination with collected core data from the Black Island Formation are useful in putting together a regional play concept for western North Dakota. Cored intervals cut from both productive and non-productive Black Island completions tend to have similar reservoir characteristics averaging approximately 5-7% porosity and 0.3 mD permeability. The inability to distinguish reservoir quality based on core data suggests the presence of a secondary reservoir characteristic: natural fractures. Proposed by Amerada Hess engineers and geologists, the Black Island Formation can be an effective vertical reservoir when a significant natural fracture system is present. Natural fracture systems appear to be most prevalent in the Black Island Formation across structural highs, where the reservoir has been stressed to the point of undergoing significant brittle deformation. In structurally quiet areas that have not undergone significant brittle deformation, the Black Island Formation lacks significant natural fractures and is an ineffective vertical reservoir. With this concept, drilling structural highs targeting the Black Island Formation may yield economic hydrocarbon flow rates, not because of structural trapping of hydrocarbons, but rather the presence of natural fractures that have formed due to structural deformation.

References

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