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Review of Ordovician Black Island Formation (Winnipeg Group) Oil and Gas Production

Timothy O. Nesheim

Edward C. Murphy, State Geologist
Lynn D. Helms, Director, Dept. of Mineral Resources
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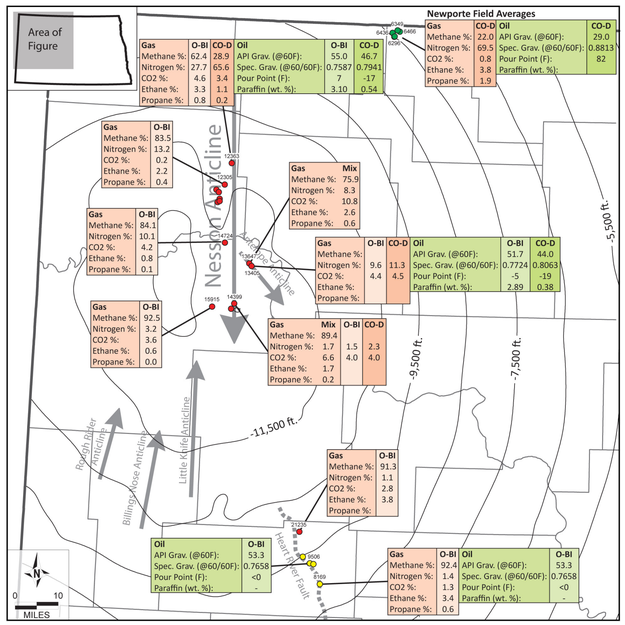

Figure 1. Map showing the distribution of productive Winnipeg/Deadwood oil and gas wells in North Dakota with oil and gas analysis data. Red dots represent dry gas wells (GOR >900), yellow dots represent wet gas wells (GOR 40-400), and green dots represent oil wells (GOR <10). O-BI = Ordovician aged Black Island Formation (Winnipeg Group); CO-D = Cambrian-Ordovician aged Deadwood Formation; GOR = Gas to Oil Ratio (1,000 ft3 to 1 barrel). NDIC numbers are posted above the wells from which oil and/or gas samples were collected and analyzed. Structure contours (subsea level depths) on the top of the Winnipeg Group are displayed by the thin black lines.

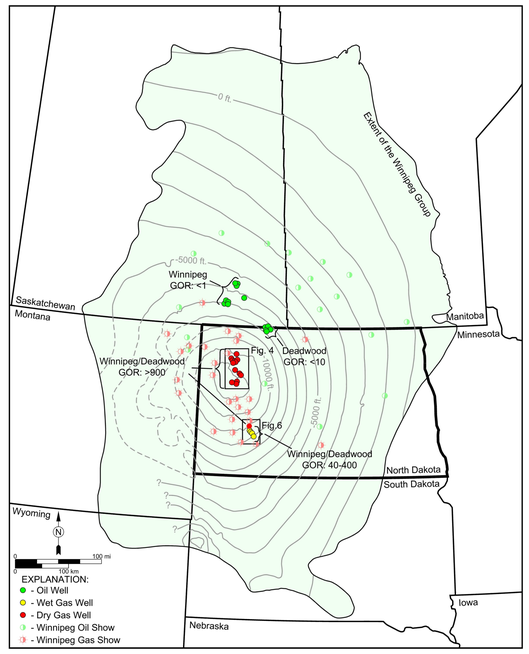

Figure 3. Regional map showing the extent of the Winnipeg Group with productive oil and gas wells completed in the Winnipeg Group and/or Deadwood Formation. The Winnipeg Group extent and structure contours (grey lines) for Saskatchewan and Manitoba were borrowed from Kreis (2004) and Bezys and Conley (1998). The Winnipeg Group extent in North Dakota was modified from LeFever et al. (1987) and estimated within South Dakota, Montana, and Wyoming. Winnipeg structure contours for North Dakota and South Dakota were generated from each state's respective oil and gas log tops databases, and for Montana were estimated using the surrounding states and provincial data sets in combination with Red River Formation structure contours from Anna (2010).

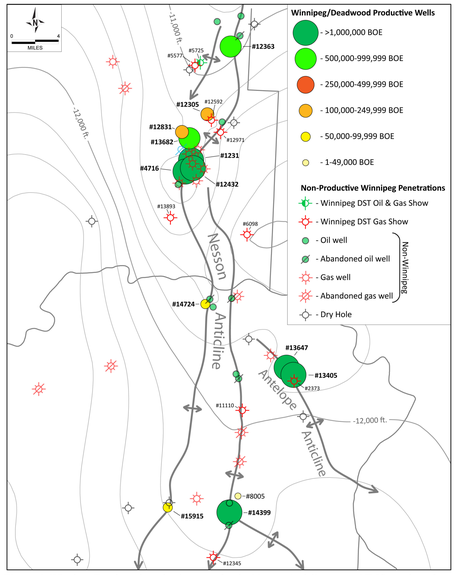

Figure 4. Winnipeg/Deadwood production map for the Nesson Anticline area. NDIC numbers from productive Winnipeg/Deadwood wells are in bold. NDIC numbers for wells with Winnipeg hydrocarbon shows are in regular, smaller sized text. Note that some of the wells illustrated as Winnipeg hydrocarbon shows were dry hole while others produced from shallower, non-Winnipeg/Deadwood intervals such as the Red River Formation.

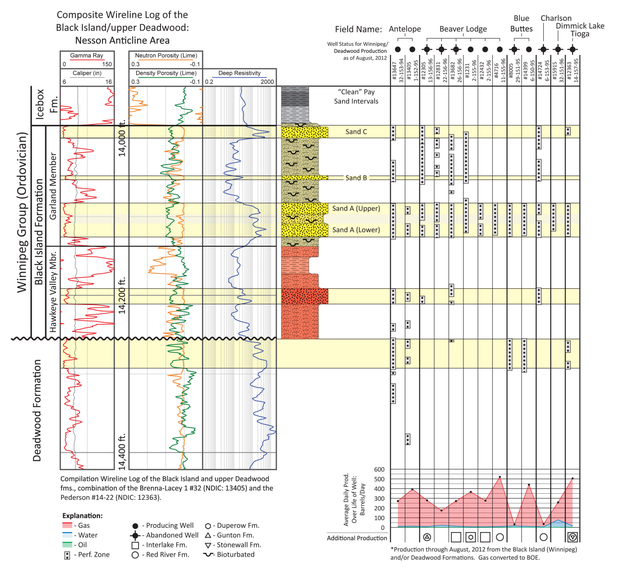

Figure 5. . Illustration depicting perforated horizons with average daily water and barrels of oil equivalent (BOE) production for Winnipeg/Deadwood productive wells along the Nesson Anticline.

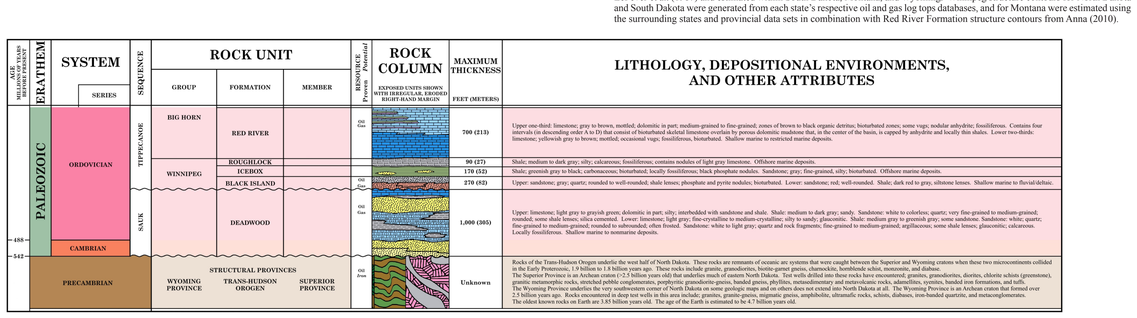

Figure 2. North Dakota's lower Paleozoic/Precambrian stratigraphic section, modified from Murphy et al. (2009).

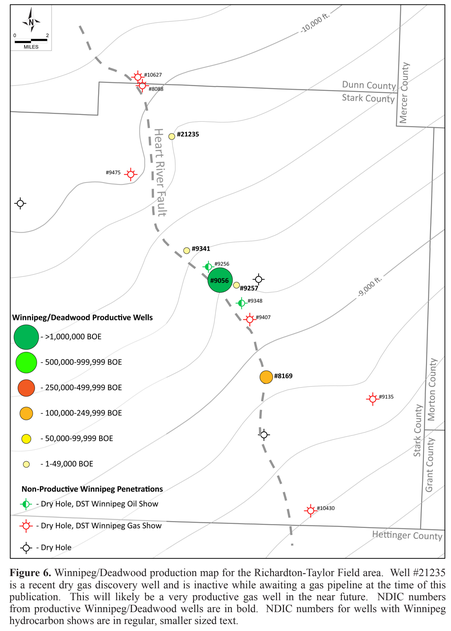

Figure 6. Winnipeg/Deadwood production map for the Richardton-Taylor Field area. Well #21235 is a recent dry gas discovery well and is inactive while awaiting a gas pipeline at the time of this publication. This will likely be a very productive gas well in the near future. NDIC numbers from productive Winnipeg/Deadwood wells are in bold. NDIC numbers for wells with Winnipeg hydrocarbon shows are in regular, smaller sized text.

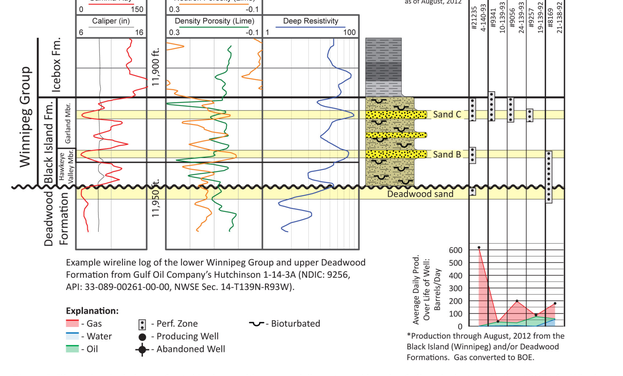

Figure 7. Illustration depicting perforated horizons with average daily water and barrels of oil equivalent production (BOE) for Winnipeg/Deadwood productive wells along the Heart River Fault.

Field	Tioga	Beaver Lodge						Charlson	Antelope	Blue Buttes	Dimmick Lake	North Taylor	Taylor			Richardton	*Totals*	*Averages*
NDIC Well Number	**#12363**	**#12305**	**#12831**	**#13682**	**#1231**	**#12432**	**#4716**	**#14724**	**#13647**	**#13405**	**#8005**	**#14399**	**#15915**	**#21235**	**#9341**	**#9056**	**#9257**	**#8169**		
Cum. BBLS Oil	3,240	1,380	362	2,173	8,038	6,456	13,118	0	13,316	15,784	0	138	20	0	486	137,982	74	3,288	*205,855*	*11,436*
Cum. BBLS Water	28,763	3,751	17,845	20,925	18,230	16,286	41,840	7,744	53,463	80,404	2,133	29,275	24,611	0	11	20,017	0	83,974	*449,272*	*24,960*
Cum. MCF Gas	8,135,823	1,619,652	876,834	3,388,174	14,924,835	12,084,613	22,890,882	392,720	11,991,056	18,992,672	12,801	12,723,358	391,152	22,145	0	6,168,848	56	1,111,332	*115,726,953*	*6,429,275*
% of Gas C1+	0.67	0.86	0.86	0.86	0.86	0.86	0.86	0.85	0.79	0.79	0.91	0.91	0.93	0.95	0.96	0.96	0.96	0.96	-	*0.88*
BOE Gas	962,691	247,847	134,177	518,475	2,283,872	1,849,247	3,502,875	59,397	1,685,575	2,669,788	2,073	2,060,188	64,798	3,743	0	1,053,753	10	189,836	*17,288,346*	*960,464*
Total BOE (Oil + Gas)	965,931	249,227	134,539	520,648	2,291,910	1,855,703	3,515,993	59,397	1,698,891	2,685,572	2,073	2,060,326	64,818	3,743	486	1,191,735	84	193,124	*17,494,201*	*971,900*
Cum. Days of Prod.	1,979	919	848	1,991	6,410	6,803	6,877	2,170	6,409	7,069	161	4,822	364	6	15	6,173	1	1,600	*54,617*	*3,034*
"Barrels" per day Gas	486.5	269.7	158.2	260.4	356.3	271.8	509.4	27.4	263.0	377.7	12.9	427.2	178.0	623.9	0.0	170.7	9.6	118.6	*4,521*	*251*
Barrels per day Oil	1.6	1.5	0.4	1.1	1.3	0.9	1.9	0.0	2.1	2.2	0.0	0.0	0.1	0.0	32.4	22.4	74.0	2.1	*144*	*8*
Barrels per day Water	14.5	4.1	21.0	10.5	2.8	2.4	6.1	3.6	8.3	11.4	13.2	6.1	67.6	0.0	0.7	3.2	0.0	52.5	*228*	*13*

Table 1. Production information for Winnipeg/Deadwood wells in North Dakota. Cum. = cumulative, OEB = barrels of oil equivalent, % of Gas C1+ = percentage of produced gas consisting of Methane (C1) + Ethane (C2) + Propane (C3).

Production Review

Over 400 oil and gas wells have penetrated the Winnipeg Group across North Dakota. To date, 18 wells have been completed in and produced from the Black Island Formation (Figs. 1-3, Table 1). Eight of these wells perforated interval/s in the underlying upper Deadwood Formation. The primarily production targets were cross-bedded to massive quartz arenites of the Black Island Formation (further described below). While there have been Winnipeg oil and gas shows reported in Manitoba and Montana, Saskatchewan is the only other state/province with Winnipeg production (Fig. 3). All Winnipeg production has come from vertically drilled wells. There have been no reported horizontal well completions in the Winnipeg to date.

The total cumulative oil production from these eighteen wells is little more than 200,000 barrels. The cumulative gas production is over 115 BCF of dry gas (Table 1). Converting the gas to barrels of oil equivalent (BOE), assuming 5,620 cubic feet of dry gas (methane) equals 1 barrel of oil, over 17 million BOE have been produced from wells that have completed and produced from the Black Island Formation, while the water production total is ~450,000 barrels. Overall, the average Black Island well has cumulatively produced 960,463 BOE with only 24,960 barrels of water. Even after 15+ years of production, Black Island completions produce very little water (<25 barrels of water/day).

Production information from the Newporte Field (Fig. 1) was not included within this study for several reasons. 1) The structure of the Newporte Field has been reported to be a meteorite impact structure (Forsman et al., 1996), which is a rare and localized feature. 2) The oil produced from the Newporte Field has a different geochemical signature than oil produced from the Winnipeg Group in other parts of the Williston Basin (Smith, 2004). 3) Castano et al. (1994) speculated that the oil in the Newporte Field was sourced from a localized source rock, which formed within the impact crater. 4) Most of the Newporte Field wells were completed in a sandstone interval located at the base of the Deadwood Formation. Overall, the Newporte Field likely represents a localized hydrocarbon accumulation which does not fit into basin-wide Winnipeg hydrocarbon exploration modeling.

Oil vs. Gas Production

Most of the Black Island hydrocarbon production to date has consisted of dry gas (80-90% + methane; Fig. 1) with gas to oil ratios (GOR) of >900 (Fig. 3). This dry gas production, however, is primarily from wells located along the Nesson Anticline (Fig. 4), where the Black Island Formation is more than 13,000 ft. deep. In southwestern North Dakota, in the Richardton-Taylor Field area (Figs. 1, 3, 6), the Winnipeg Group produces wet gas from depths of approximately 11,000 ft. with of GOR's of 40-400 (Fig. 3). Moving to shallower parts of the basin, hydrocarbon production from the Deadwood Formation within Newporte Field, though unique geologically and localized, is primarily oil with GOR's of less than 10 (Figs. 1 and 3) from depths of around 9,000 ft. Winnipeg (Black Island) production from depths of ~7,000 ft. in southeastern Saskatchewan consists of 40-55 API gravity oil with GOR's of less than 1 (Fig. 3). Based on this overall shift from dry gas production in the central portions of the Williston Basin to primarily oil production in the shallower regions of southeastern Saskatchewan, the Black Island Formation has potential to be a significant oil producer in the shallower parts of North Dakota's Williston Basin.

Winnipeg Petroleum System Overview

Source

The Icebox Formation (Figs. 2, 5, 7) consists of shale that is sometimes interbedded with siltstones and sandstones. Icebox shale has been traditionally considered a significant hydrocarbon source rock interval within the Williston Basin (Dow, 1974; Williams, 1974). From a set of 11 samples, Williams (1974) listed the Icebox at 0.42 wt. % TOC. However, for southeastern Saskatchewan and southwestern Manitoba, Osadetz et al. (1992) reported the Icebox Formation averages 1.55 wt. % TOC with an S1 + S2 of ~12 mg/gm. This classifies as an overall good quality source rock (Dembicki, 2009). Most recently, Seibel (2002) examined the source rock potential of shales within both the Icebox and Black Island formations in southeastern Saskatchewan. The Icebox samples collected and analyzed by Siebel (2002) averaged ~2.2 wt. % TOC, comparable to the Osadetz et al. (1992) average, but notably varied between wells sampled. Siebel (2002) also noted that shale intervals within the Black Island Formation also had some hydrocarbon generation potential based on geochemical analysis.

Reservoir

The Black Island Formation (Figs. 2, 5, 7) consists primarily of bioturbated siltstones and fine grained sandstones interbedded with dark grey to black shale and well sorted, rounded to well rounded, medium grained, massive to cross-bedded quartz arenite. The quartz arenite intervals are the primarily reservoir of Black Island completions, which are observed in wireline logs by their very low gamma gray signature (Sands A-C in Figs. 5 & 7). In the deeper portions of the basin, where the Black Island Formation is hydrocarbon productive along the Nesson Anticline, core measured porosity and permeability values typically range from 5-10% and 0.1-10 millidarcies. Occasionally, core permeability measurements of >100 millidarcies are observed. Finding porous and permeable Black Island sandstone intervals may be more difficult than finding hydrocarbon charged intervals. Sandstone intervals also occur within the Icebox Formation and have yielded oil shows (Kessler, 1991; Ulishney et al., 2005), particularly in northwestern North Dakota and the surrounding area, but have not proved economically productive.

Seal

The Black Island Formation is overlain by the >200 ft. thick, shale-dominate Icebox Formation (Fig. 2), which may serve as both source and seal. While sandy intervals occur within the Icebox Formation, they tend to be overlain by thick sections of shale. There are also shale intervals within the Black Island Formation that may act as localized seals, and in some locations minimize fluid communication between the Black Island and Deadwood Formations. The lower portions of the overlying Red River Formation consist of very tight (<2% based on porosity logs) limestone, which likely negates any upward migration of Icebox generated hydrocarbons and thereby forces downward migration into the Black Island Formation.

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