North Dakota Geological Survey
Geologic Investigations No. 150

Spearfish Formation - Another Unconventional Target

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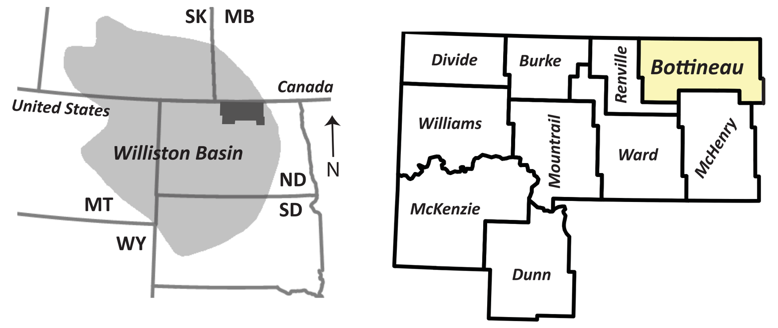
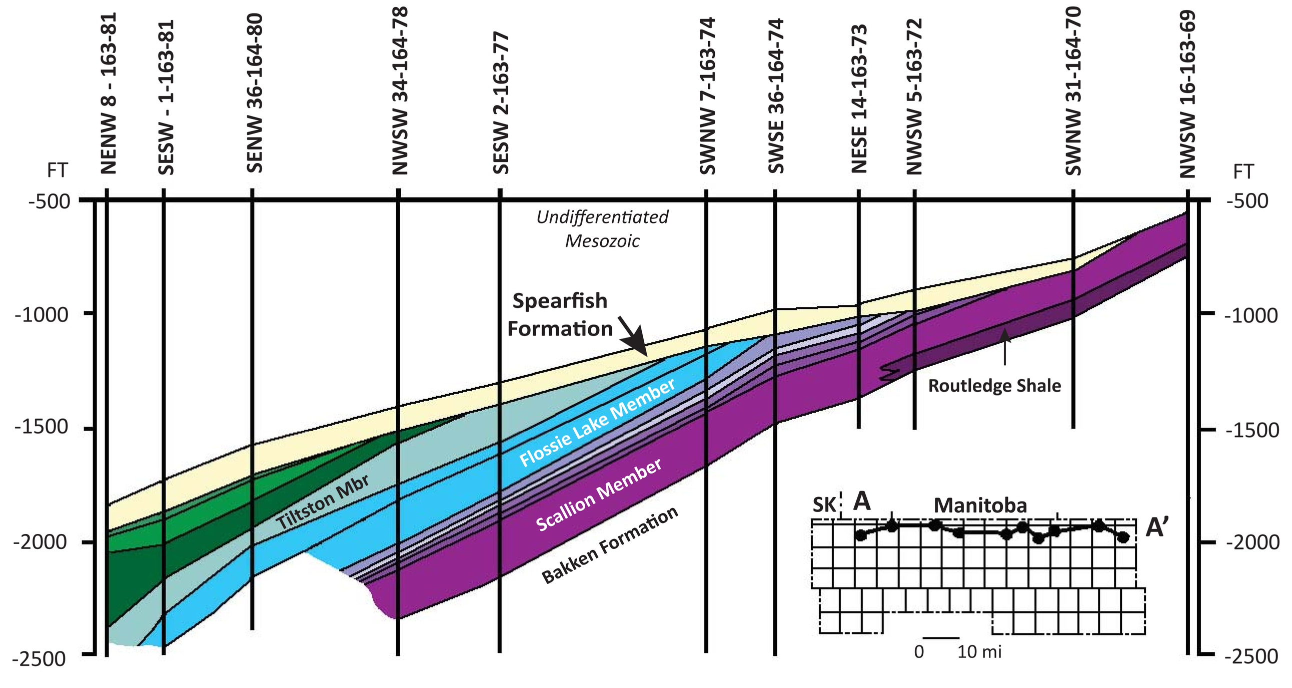
2012



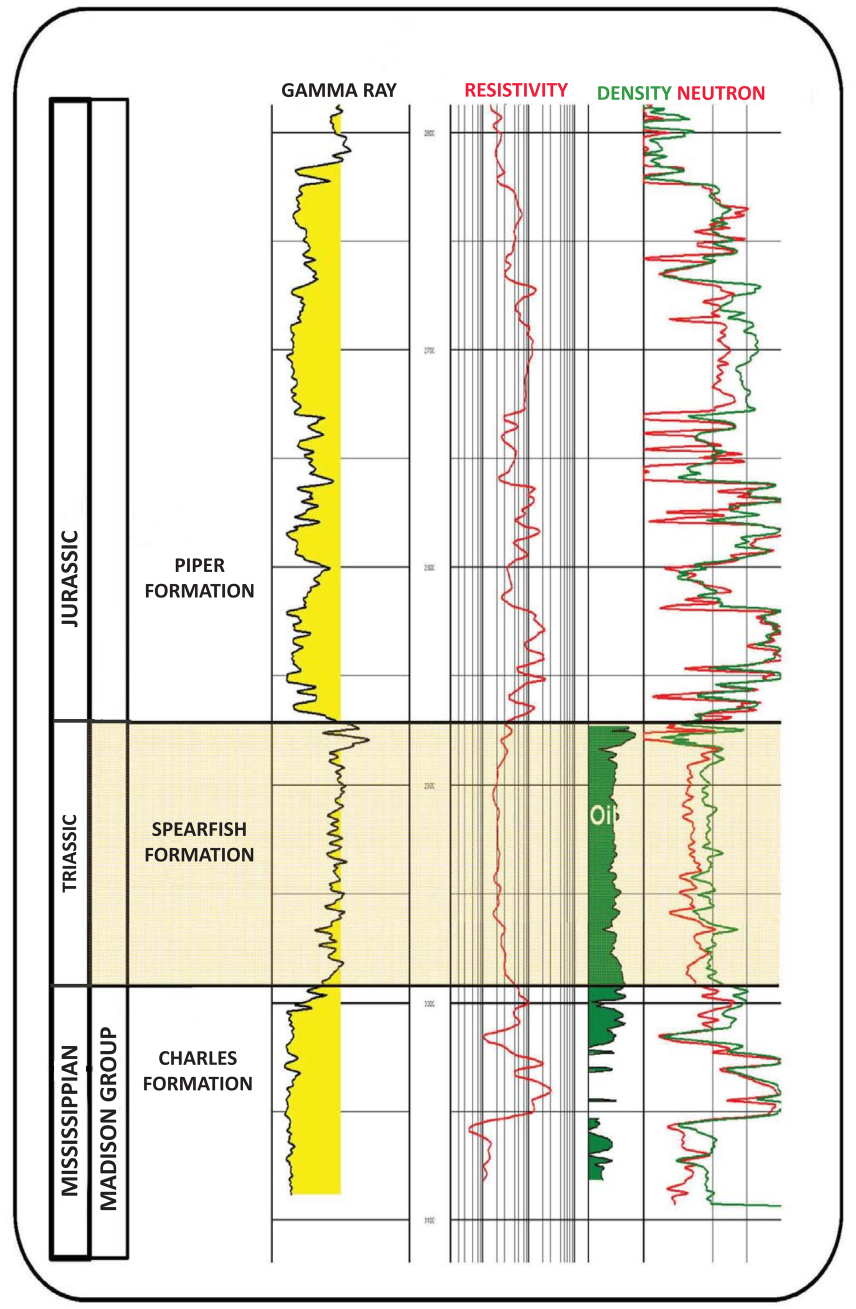
Index map with the area of interest indicated in yellow.

		North Dakota	Saskatchewan	Manitoba
TRIASSIC/JURASSIC (?)	Spearfish Formation	Saude Member	Lower Watrous	Lower Amaranth
		Pine Salt Member		
		Belfield Member		

Stratigraphic nomenclature of the Spearfish Formation.



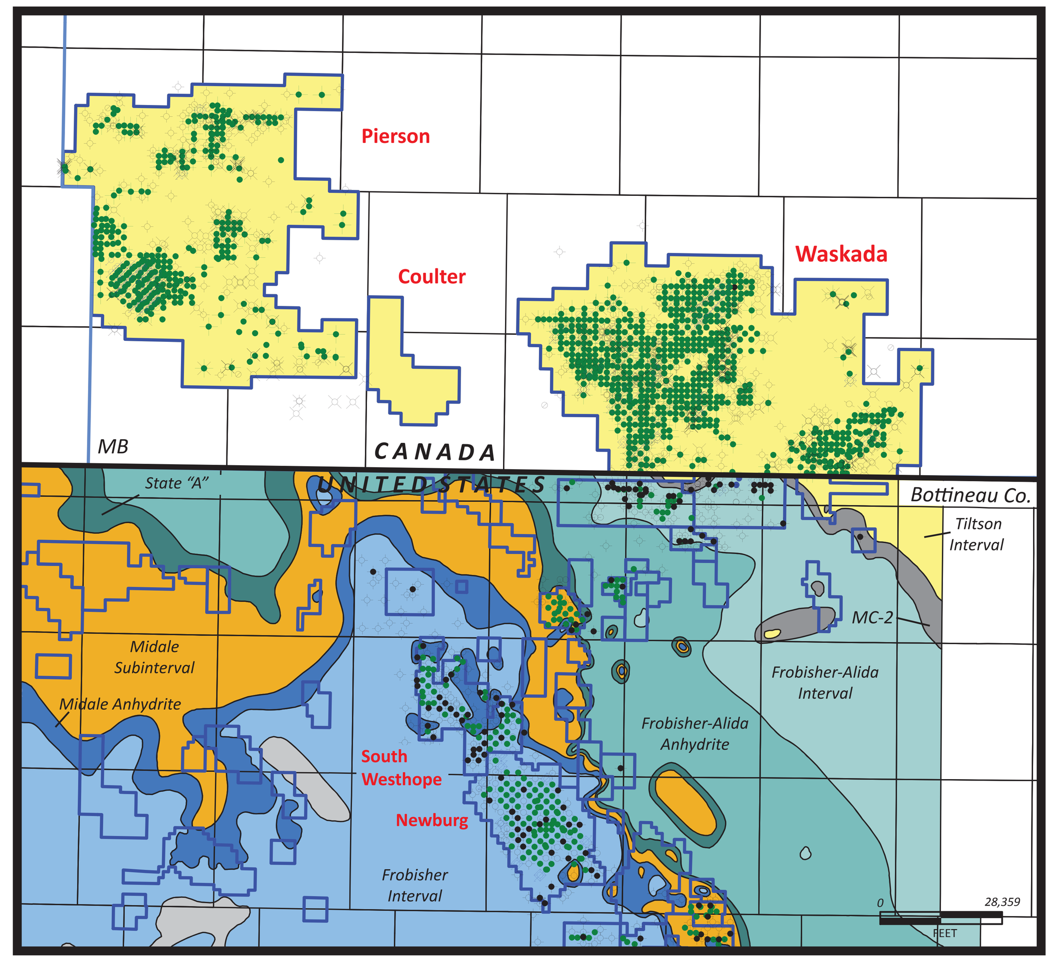
Schematic cross-section showing the onlap of the Spearfish Formation over the Madison unconformity surface in Bottineau County, North Dakota. The shades of green represent the various members within the Mission Canyon Formation. The shades of blue and purple represent members of the Lodgepole Formation (modified from LeFever and LeFever, 1991).



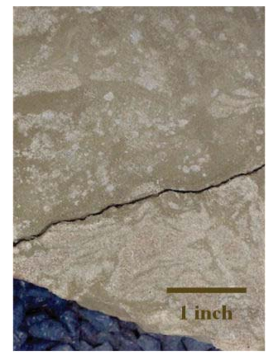
Representative wireline log from the current play in the Spearfish Formation (modified from Papa, 2010).

	Southwestern Manitoba	North-Central North Dakota
Formation	2935 TVD	3000 ft TVD; 5,500 ft MD
Thickness	78	50 ft
Average Porosity	14.5%	14%
API Oil Gravity	35°	36°
Initial IPs	208-337 Bopd	285-305 Bopd
Oil-in-Place/Section	9-15 MMbo	13 MMbo

A comparison of the reservoir characteristics of the current Spearfish play (Papa, 2010; Redekop 2010, NDIC Case #12076).



Paleozoic subcrop map underlying the Spearfish Formation for Bottineau County with informal units indicated in italics. Field boundaries are shown in blue with the major Spearfish producing fields on both sides of the international border labelled in red.



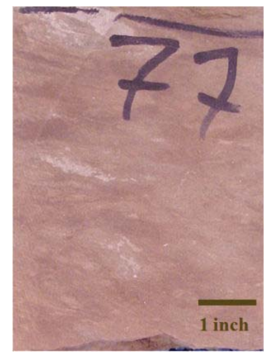


Photo 1 - Newburg Field Spearfish Pay sandstone at depth of 3357 ft (Amerada Hess Corp - Newburg-Spearfish-Charles Unit P-713, NENE Sec. 16, T161N, R79W; 33-009-01390-0000).

Photo 2 - Typical Spearfish shale bed at a depth of 2977 ft (Norcen Energy Inc - Lindstrom 34-1, NW NW Sec. 34, T164N, R78W; 33-009-01599-0000).

Photo 3 - Spearfish shale with anhydrite nodules at a depth of 2987 ft (Norcen Energy Inc - Lindstrom 34-1, NWNW Sec. 34, T164N, R78W; 33-009-01599-0000).

Photo 4 - Spearfish sandstone bed with rip-up clasts at a depth of 3020.5 ft (Norcen Energy, Inc - Lindstrom 34-1, NWNE Sec. 34, T164N, R78W; 33-009-01599-0000).

Representative core photographs of the Spearfish Formation form producing wells in Bottineau County.

Spearfish Formation

The production history from the Spearfish Formation (Triassic) in the state is similar to the drilling history of the Bakken Formation and other unconventional reservoirs. Drilling in Bottineau County began with a random wildcat, the Zach Brooks Drilling Company - #1 Edwin Berentson (SWSE Sec. 21, T163N, R79W). Drilled and completed in November 1952, this well was the first commercial oil well in Bottineau County and the discovery well for Westhope Field. Early wells in the county produced primarily from the Madison Formation (Mississippian) but strong oil shows in the overlying Spearfish suggested that it might also be a target. Subsequent discoveries at Newburg (1955) and South Westhope (1956) fields proved this to be true.

Drilling activity reached record highs from 1957 to 1959 and continued through 1961 in the region as companies actively pursued the Madison and Spearfish Formations (LeFever and LeFever, 1991). It is interesting to note that marketing the oil in this area was difficult early in the exploration history of the region. Production in the north-central portion of the basin was marked by rail in 1963 and then through the Portal Pipeline to refineries in Minnesota and Wisconsin. A successful waterflood was initiated by Amerada Petroleum Corporation in 1967 to reverse the gradual declined of production in Newburg Field. Drilling activity slowed basinwide from 1966 to 1974 (Gerhard et al., 1982).

A discovery by Omega Hydrocarbons Ltd. in June 1980 resulted in renewed activity when the company recompleted a Madison producer in the Lower Amaranth (Spearfish equivalent) in Waskada Field, Manitoba (Barchyn, 1982). Oil production is from an interbedded sequence of shales, siltstone and sandstones that were probably deposited in an intermittently shallow, restricted marine environment. This discovery was followed by a significant lease play in north-central North Dakota but the drilling success rate was variable and the play did not develop as expected. The play in southern Manitoba continued until 1990 when exploratory drilling became non-economic. Production from these fields continued with horizontal development drilling coupled with secondary recovery methods.

Early in 2008, EOG Resources revisited the Waskada Field area with technology used to explore for the Bakken Formation in Mountrail County. The application of horizontal drilling in combination with fracture stimulation resulted in wells that produce exponentially better than traditional vertical wells (Redekop, 2010). Drilling and production is continuing in Manitoba with the average per well cost of $1.5 million.

EOG Resources announced in April 2010 that they had moved the Spearfish play across the border into north-central Nor th Dakota. This extension, referred to as the Waskada South Field, is considered to be a small accumulation (20 million barrels) with a very high rate of return (Papa, 2010). Limited success resulted in the sale of their holdings to Surge Energy Inc. on April 2011, activity of these holdings are pending an increase in bank line (Surge Energy Corp., April 7, 2011 News Release).

Legacy Oil and Gas Inc. moved into the North Dakota portion of the Spearfish with their acquisition of land to the east of the EOG/Surge properties. Five wells were drilled in late 2010/early 2011 using coiled tubing and multi-stage fracture stimulation. One of the wells drilled was a mechanical failure and another is waiting on a service rig. The remaining three are on production, with an average 60 day initial production rate of 100 BOE per day per well (Legacy Oil & Gas Inc., August 9, 2011 News Release). With this success, the company has permitted 14 additional well locations.

Spearfish Formation

The Spearfish Formation in North Dakota occurs only in the subsurface, and consists of three members, in ascending order: the Belfield, the Pine Salt, and the Saude. The formation is present over half of the state, reaching a maximum thickness of 750 ft.

Only the uppermost member of the Spearfish Formation is present in the north-central portion of the state at a depth ranging from 2900 to 3400 ft. The Spearfish onlaps the Madison unconformity surface in Bottineau County and into southern Manitoba where it is productive. This portion of the formation over the study area is a 125 to 220 ft thick red bed sequence consisting primarily of the quartzose sandstones that are occasionally cemented with anhydrite or having anhydrite nodules, siltstones, shaly sandstones, and some thin anhydrite beds (Dow, 1967, LeFever and LeFever, 1991).The sequence of shales, siltstones, and sandstones that comprise the Spearfish Formation were deposited in a subtidal to supratidal environment. The sandstones were probably derived from coastal dunes that were inundated by transgressive seas. The reworking and re-deposition of these sands resulted in a widespread sheet like morphology. Periodic emergence resulted in evaporitic conditions and extensive oxidation. In addition, a series of subtidal channels cross cut the interval. These deposits are characterized by channel lags (recognizable on logs and highly cemented), trough cross-bedding, and by planar bedded and current rippled sandstones (the trough cross-bedded and planar bedded facies are the reservoir facies at Russell, Starbuck and South Starbuck fields (LeFever and LeFever, 1991; Oglesby and Fischer, 1991).

Newburg and South Westhope

Production in Newburg and South Westhope is from both the Spearfish and the underlying Charles Formation. These fields produce from a stratigraphic trap that occurs on the updip limb of a syncline formed from the dissolution of the underlying Prairie Salt (Devonian). The productive section of the Spearfish is unlike the majority of the overlying section because it is represented by a pale grey-green color. The color change probably results from reducing conditions due to oil emplacement and may be responsible for a noted increase in the porosity and permeability of the productive section.

The Spearfish pool ranges in thickness from 10 to 40 ft within the fields. The effective pay may be significantly less depending on the lithology. The reservoir has measured intergranular porosities of 12 to 15% with permeabilities ranging from <0.1 to 320 md. Water saturation can be as high as 50 to 60% and oil saturations range from 0 to 37% and vary on a well to well basis. The reservoir is undersaturated with gas-oil ratios of 100:1 or less. Production is aided by natural and secondary water drives

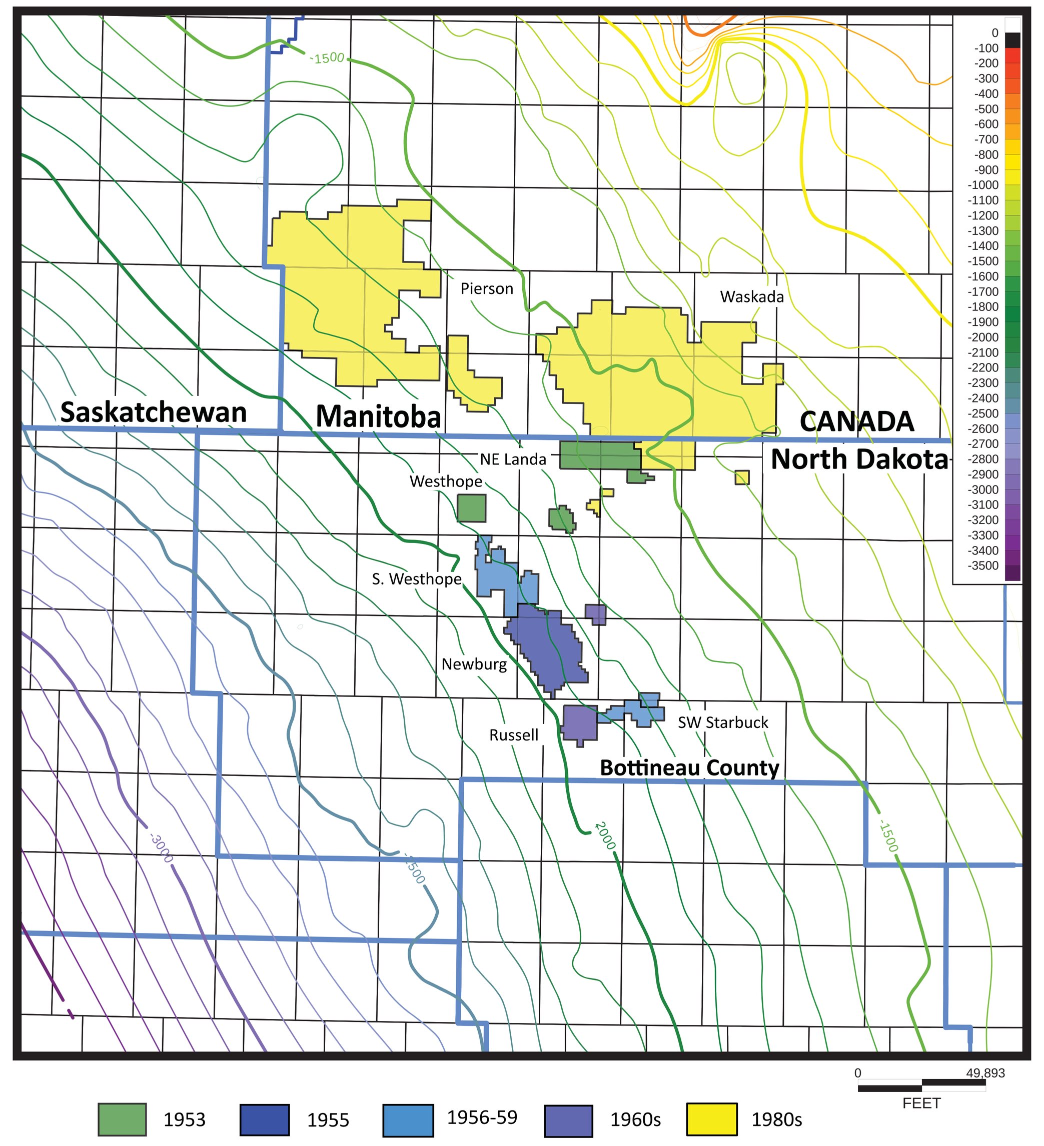
Waskada and Pierson

The Lower Amaranth pools (Spearfish equivalent) in Waskada and Pierson fields are represented by red dolomitic siltstones and sandstones interbedded with argillaceous siltstones and shale. Barchyn (1982) noted that the dolomite is associated primarily with the finer grained silty material, whereas anhydrite cements the coarser sandy material and occurs as nodules and lenses.

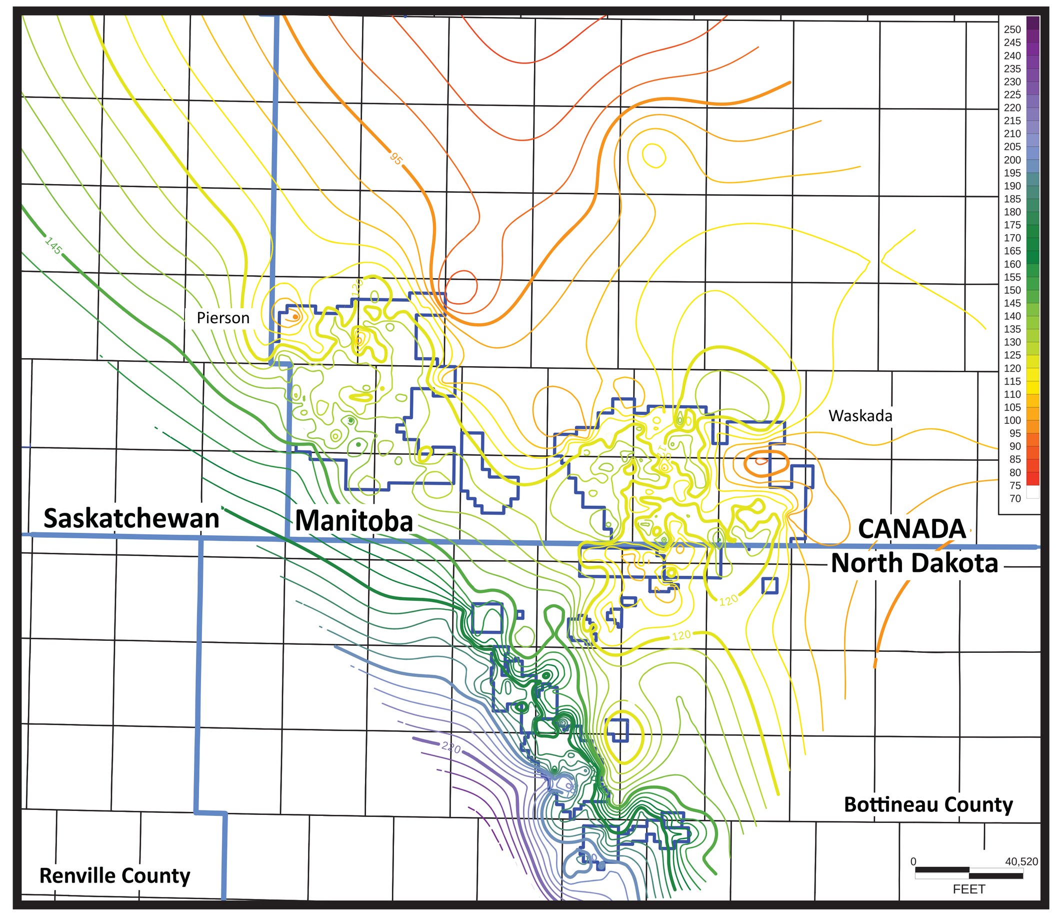
Again, the trap is stratigraphic with the reservoir located in the coarser grained siltstones, the siltstones and sandstones. Porosities average 14.5% with an average permeability of 14.8 md. Slightly higher values have been noted from the sandstones at Pierson Field (Husain, 1990). The fields were initially developed with vertical wells followed by secondary recovery through waterflooding. Horizontal drilling has successfully increased production and reserves.

Current Activity

As previously stated, the current activity is continuing with Legacy Oil and Gas Inc. and is focusing on the redbed portion of the Spearfish Formation. The Spearfish in this area is underlain by productive Madison instead of Frobisher-Evaporite that acts as a seal immediately south of Waskada Field. Drilling using coiled-tubing and multi-stage fracture stimulation has opened the entire section to production.



Structure on the top of the Madison unconformity surface. The distribution of Spearfish producing oil fields in Bottineau County, North Dakota and Canada are also indicated. The fields are colored based on the discovery date (modified from LeFever and LeFever, 1991).



Isopach of the Spearfish Formation. The distribution of Spearfish producing oil fields in Bottineau County, North Dakota and Canada are also indicated. The fields are colored based on the discovery date (modified from LeFever and LeFever, 1991).

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Papa, B., 2010, EOG Resources, Rocky Mountain Oil, Quarterly Report to Investors.
Redekop, B, Southwest Manitoba welcomes oil slick: Winnipeg Free Press, Feb. 20 2010.

Canadian Field Data

Horizontal Drilling Methods:

Drilling:
Single leg monobore to toe, using mud motors, typically 500 to 750 m in length;
Multiple parallel wellbores.

Completion Method 1:
Production casing is run to TD and cemented to surface;
Tuging conveyed perforating guns, with 15-23, 1m, O degrees phase guns, shooting straight up (9 shots/m);
Coiled tubing conveyed frac assembly with packers at 5 m intervals. 250L of acid pumped followed by 5 ton sand frac.

Completion Method 2:
Production casing is run to TD and cemented to surface;
Coiled tubing conveyed brazer jet and packer "Mongoose Tool" perforates and fracs in the same run (4 jets at .3m intervals and 60 degree phasing;

Completion Method 3:
Downhole frac ports are installed in production casing string at 20 -50 m intervals;
Frac ports are isolated and the frac proceeds as normal (4 ports per collar at 90 degrees).

Known Reservoir Issues:

1. A heterogeneous pore system and abundant ineffective porosity within the matrix material;
2. Migrating fines, such as illitic clays and authigenic kaolinite;
3. The presence of swelling clays;
4. Pyrite that may convert to iron hydroxide gels in the presence of hydrochloric acid;
5. Dolomite that may form calcium fluoride precipitates in the presence of hydrofluoric acid; and,
6. Anhydrite cement which may form calcium sulfate scales if formation water and hydrocarbons are produced together from this reservoir.

Summary of XRD Analysis

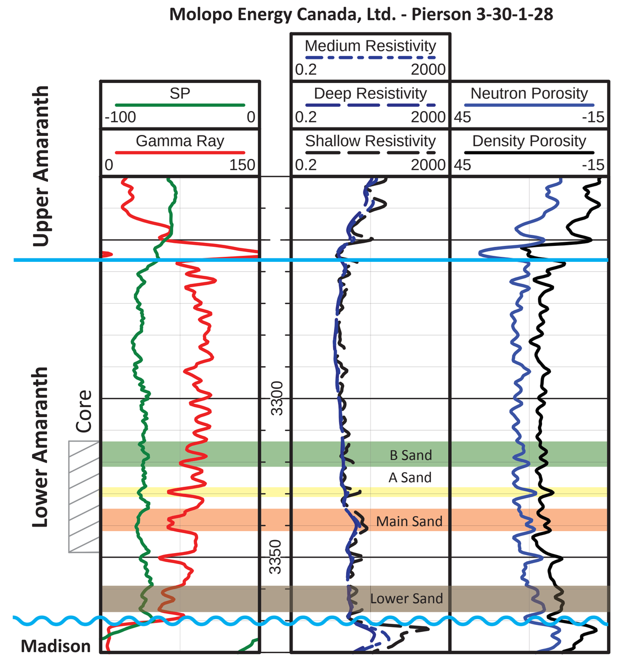
Company: Molopo Energy Canada Ltd. — Work Order No. A-14810
Location: 100/08-25-001-28W1M and 100/03-30-001-28W1M — January, 2010

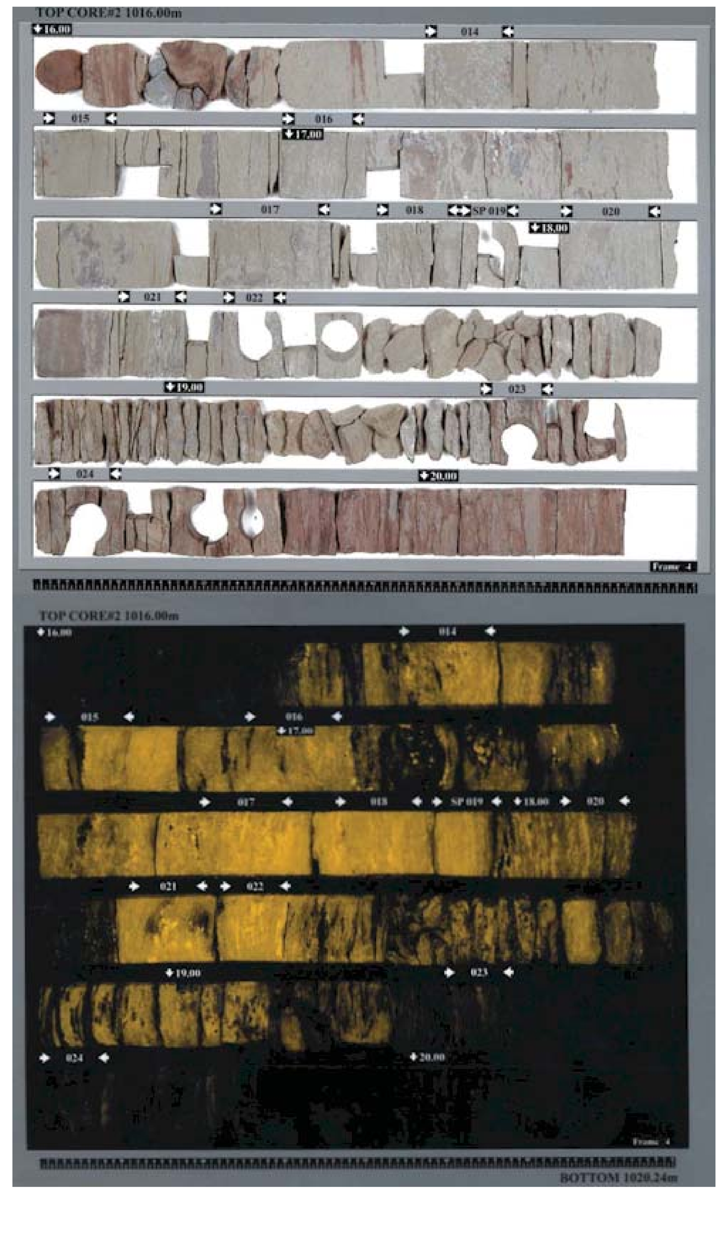
SAMPLE ID.	TYPE OF ANALYSIS	WEIGHT %	Qtz	Plag	K-Feld	Cal	Dol	Anhy	Pyr	Musc	Bar	Sider	Kaol (CLAYS)	Chl (CLAYS)	Ill (CLAYS)	ML (CLAYS)	Smec (CLAYS)	Total Clay
100/08-25	BULK FRACTION:	95.93	28	5	8	0	19	36	0	0	0	0	0	0	4	0	0	4
2	CLAY FRACTION:	4.07	0	0	0	0	3	5	0	0	0	0	5	0	33	0	54	92
978.13m	BULK & CLAY	100	26	5	8	0	19	35	0	0	0	0	TR	0	5	0	2	7
100/08-25	BULK FRACTION:	89.58	12	0	1	1	80	0	0	0	0	0	0	0	6	0	0	6
3	CLAY FRACTION:	10.42	0	0	0	0	7	0	0	0	0	0	10	0	41	0	42	93
979.20m	BULK & CLAY	100	10	0	1	1	73	0	0	0	0	0	1	0	10	0	4	15
100/03-30	BULK FRACTION:	91.20	45	5	2	0	28	16	0	0	0	0	0	0	4	0	0	4
6	CLAY FRACTION:	8.80	2	0	0	0	0	0	0	2	0	0	11	5	80	0	0	96
1010.18m	BULK & CLAY	100	42	4	2	0	26	14	0	TR	0	0	1	TR	11	0	0	12
100/03-30	BULK FRACTION:	92.70	53	5	7	0	22	9	0	0	0	0	0	0	4	0	0	4
7	CLAY FRACTION:	7.30	0	0	0	0	7	0	0	1	0	0	26	0	53	13	0	92
1016.35m	BULK & CLAY	100	49	5	6	0	21	9	0	TR	0	0	2	0	7	1	0	10
100/03-30	BULK FRACTION:	95.93	53	3	4	0	21	15	0	0	0	0	0	0	4	0	0	4
9	CLAY FRACTION:	4.07	2	0	0	0	4	0	0	0	0	0	18	12	52	12	0	94
1018.76m	BULK & CLAY	100	51	3	4	0	20	14	0	0	0	0	1	TR	6	1	0	8

Best Completion & Production Practices:

1. Fracture stimulation to create a more homogenous production environment, improve interconnection of isolated pores and increase flow rates.
2. Holding production rates under a critical velocity flow may may avoid migration of fines.
3. Avoiding production of formation water with oil to prevent the precipitation of calcium sulfate scales.
4. Avoiding hydrochloric and hydrofluoric acids to prevent precipitation of iron hydroxide gels and calcium fluoride precipitates.
5. Avoiding fresh water based drilling muds in areas of smectite clays.

100/03-30-001-28W1-00
Molopo Energy Canada, Ltd. - Pierson 3-30-1-28





Example of the producing Lower Amaranth, Spearfish equivalent section from Pierson field in Manitoba, Canada. Core photographs are provided to the right. Porosities increase with the lighter color and are associated with the sandier, cleaner gamma ray sections (Fulton-Regula, 2011). Core issues and best completion and production practices for the Manitoba fields are listed above. XRD data prepared for Molopo Energy Canada, Inc by Agat Laboratories.