Initial report to Stratex Oil and Gas concerning:

Bakken Formation Sourced Oils beneath Stratex leased land in Sheridan County, Montana
September 7th, 2011

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A geological investigation of the hydrocarbon potential of the land leased by Stratex Oil and Gas in Sheridan County, Montana was done using information obtained through professional publications and from the Montana Board of Oil and Gas Conservation (MBOGC). A portion of the results of that investigation are found in this report.

Multiple formations have produced oil in northeastern Sheridan County, Montana and Divide County, North Dakota (borders Sheridan County) including the Red River, Duperow, Birdbear, Bakken, Lodgepole and the Madison Group carbonates. Clearly, having multiple objectives beneath the land leased by Stratex Oil and Gas adds value to the leased land. Each of these formations has a different set of geologic features that enables them to economically produce oil. These features are detailed in this and successive reports on the hydrocarbon potential of this area.

The upper Bakken formation is an organic black shale, approximately 10 feet thick, which is thermally mature in Sheridan County. The upper Bakken acts as the source rock for several formations, including the middle Bakken and overlying lower Lodgepole formations. Several horizontal wells in the Flat Lake field in Sheridan county targeted the middle Bakken (approximately 50 feet thick) and have had impressive
initial production rates that were in the 10,000 to 13,000 barrels a month range. These wells were drilled to depths of approximately 7,700 feet.

The lower Bakken formation is also an organic black shale, approximately 20 feet thick, which is thermally mature in Sheridan County. The lower Bakken acts as the source rock for several formations, including the Three Forks and Birdbear (Nisku) formations, which are vertically below the lower Bakken. The Birdbear (Nisku) formation has a lower carbonate complex and an upper carbonate-evaporite complex and is approximately 100 feet thick in northeastern Sheridan County. Production from the lower carbonate complex comes from bioherms and from an 8 to 20 feet thick porous zone within the complex. Production from the lower carbonate complex comes from structural highs that are related to solution collapse features from the dissolution of the Devonian Prairie salt formation. The Birdbear has had impressive initial production from the Flat lake field, with rates of up to 9,000 barrels a month. These wells were drilled to depths of approximately 8,000 feet. In North Dakota, the upper Birdbear produces oil from a relatively thin dolomitized layer sandwiched between anhydrite layers. This play may not have been fully explored in Sheridan County and may be of interest to Stratex Oil and Gas.

The Three Forks is approximately 150 feet thick in Sheridan County and does not appear to have been tested where Stratex Oil and Gas has its property. The upper Three Forks is a productive target in North Dakota, where horizontal drilling and hydraulic fracturing has been successfully used to produce oil from dolomitic sandstones and siltstones. This may be an attractive target for hydrocarbon exploration in Sheridan County.

Production from both the middle Bakken and Three Forks formations throughout the Williston Basin is enhanced by the presence of natural fractures and carbonate diagenesis. Dissolution and subsequent collapse of the underlying Prairie salt beneath Sheridan County may have substantially fractured these formations and may result in enhanced production in horizontal wells drilled into this formation. Carbonate diagenesis, including the dolomitization of existing carbonates sediments and porosity
enhancement due to meteoric diagenesis (Birdbear), has occurred in nearby fields in Montana and in Saskatchewan, Canada and may increase production from these formation beneath the land leased by Stratex Oil and Gas as well.

Successful wells in Sheridan County used a variety of different strategies to produce oil. The Bakken formation was drilled using horizontal wells whereas the Birdbear and Red River formations were drilled using vertical wells that targeted structural highs. Seismic work will be needed (new or reprocessed) to determine if structural highs are present in these formations (Red River and Birdbear) beneath the land leased by Stratex Oil and Gas.

Additional reports on the Red River, Lodgepole and Madison Group carbonate will follow.

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Queens, NY 11694
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1. Sheridan County Overview:

Stratex Oil and Gas is currently leasing acreage and is considering leasing additional acreage in the northeastern Sheridan County, Montana. This land is located in three separate parcels, T37N – R56E (sections 22, 23 and 24), T37N – R57E (sections 9, 10 and 15) and T36N – R58E (sections 19, 20, 28, 29, 30, 31 and 32) (Fig. 1). Oil and natural gas is currently being produced from multiple formations in this area, including the Bakken; Ratcliff (Madison Group); Nisku (Birdbear); Red River, Lodgepole and Mission Canyon formations (Fig. 2) (Tables 1 to 6).

Knowledge of the migration of oil from source rock to the reservoir formations and the volumes of oil produced can aid Stratex Oil and Gas with their exploration plans. Dow (1974) initially divided Williston Basin oils into three groups. Type I oil was derived from Ordovician Winnipeg shale and was the source rock for the Red River formation. Type II oil was derived from the Bakken shale and was the source rock for the Bakken formation and Madison Group carbonates. Type III oils were derived from the Tyler formation and were confined to this formation. Jarvie (2001) grouped oils in the Williston Basin by their chemical fingerprint and separated the oils into separate petroleum systems. He indicated that the Red River formation oils belonged to a separate petroleum system which included the Interlake formation and Winnipeg formation oils; the Madison Group oils belonged to a separate petroleum system and the Bakken formation oils belonged to a separate petroleum system, which included the Lodgepole formation, Nisku (Birdbear) formation and Three Forks formation oils.

This report will concentrate on the Bakken petroleum system in Sheridan County, Montana. The Red River and Madison oil systems will be addressed in subsequent reports.
**Fig. 1.** Land leased by Stratex Oil and Gas in Sheridan County, Montana, T37N – R56E (sections 22, 23 and 24), T37N – R57E (sections 9, 10 and 15) and T36N – R58E (sections 19, 20, 28, 29, 30, 31 and 32).

Source: Stratex Oil and Gas, 2011
Fig. 2. Paleozoic stratigraphic column for Montana. The Devonian Birdbear is also informally referred to as the Nisku formation.
Table 1. Selected wells in 37N – 57E, section 9.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Well Name</th>
<th>Well Type</th>
<th>Producing Formation</th>
<th>Formation Top (ft)</th>
<th>I/P Oil bbls/month</th>
<th>I/P Gas mcf/month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat Lake</td>
<td>Hellegaard(1) H</td>
<td></td>
<td>Bakken</td>
<td>7,750</td>
<td>13,499</td>
<td>2,317</td>
</tr>
<tr>
<td></td>
<td>9-12h</td>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat Lake</td>
<td>Hellegaard(1) H</td>
<td></td>
<td>Bakken</td>
<td>7,976</td>
<td>9,850</td>
<td>1,911</td>
</tr>
<tr>
<td></td>
<td>9-13h</td>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat Lake</td>
<td>McKinnon(1) V/H</td>
<td></td>
<td>Birdbear</td>
<td>7,950</td>
<td>1,802</td>
<td>1,246</td>
</tr>
<tr>
<td></td>
<td>3 H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) currently producing
(2) shut in
I/P = initial production
H = horizontal, V = vertical, V/H = original vertical - recompleted to horizontal

Table 2. Selected wells in 37N – 57E, section 10. These wells came from the southern half of the section. The top half of the section contained 3 dry holes.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Well Name</th>
<th>Well Type</th>
<th>Producing Formation</th>
<th>Formation Top (ft)</th>
<th>I/P Oil bbls/month</th>
<th>I/P Gas mcf/month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat Lake</td>
<td>Hellegaard(2) H</td>
<td></td>
<td>Birdbear</td>
<td>7,902</td>
<td>9,813</td>
<td>5,702</td>
</tr>
<tr>
<td></td>
<td>4h</td>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat Lake</td>
<td>Hellegaard(1) H</td>
<td></td>
<td>Bakken</td>
<td>8,080</td>
<td>13,352</td>
<td>2,085</td>
</tr>
<tr>
<td></td>
<td>10-16h</td>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat Lake</td>
<td>Heppner (1) H</td>
<td></td>
<td>Ratcliffe</td>
<td>6,445</td>
<td>1,448</td>
<td>0</td>
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<tr>
<td></td>
<td>1h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat Lake</td>
<td>Heppner (1) V/H</td>
<td></td>
<td>Birdbear</td>
<td>7,901</td>
<td>6,698</td>
<td>3,322</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) currently producing
(2) shut in
H = horizontal, V = vertical, V/H = vertical recompleted to horizontal
### Table 3. Selected wells in 37N – 57E, section 15.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Well Name</th>
<th>Well Type</th>
<th>Producing Formation</th>
<th>Formation Top (ft)</th>
<th>I/P Oil (bbls/month)</th>
<th>I/P Gas (mcf/month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat Lake</td>
<td>H Hellegaard(1)</td>
<td>H</td>
<td>Bakken</td>
<td>7,687</td>
<td>7,363</td>
<td>1,260</td>
</tr>
<tr>
<td>Flat Lake</td>
<td>8h Hellegaard(1)</td>
<td>H</td>
<td>Birdbear</td>
<td>8,224</td>
<td>711</td>
<td>54</td>
</tr>
<tr>
<td>Flat Lake</td>
<td>4h wflnuJerde(1)</td>
<td>H</td>
<td>Birdbear</td>
<td>7,922</td>
<td>5,372</td>
<td>1,960</td>
</tr>
<tr>
<td>Flat Lake</td>
<td>4h Jerde 6h(1)</td>
<td>H</td>
<td>Birdbear</td>
<td>7,887</td>
<td>3,142</td>
<td>476</td>
</tr>
<tr>
<td>Flat Lake</td>
<td>cpJerde 2(1)</td>
<td>V</td>
<td>Ratcliffe</td>
<td>6,431</td>
<td>1,890</td>
<td>550</td>
</tr>
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</table>

(1) currently producing  
(2) shut in  
I/P = initial production  
H = horizontal, V = vertical, V/H = vertical recompleted to horizontal

### Table 4. Selected well from 37N – 56E, section 14. This well is located on the section just to the north of sections 23 that are leased by Stratex Oil and Gas. There are no producing wells on sections 22, 23 and 24.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Well Name</th>
<th>Well Type</th>
<th>Producing Formation</th>
<th>Formation Top (ft)</th>
<th>I/P Oil (bbls/month)</th>
<th>I/P Gas (mcf/month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt Lake West</td>
<td>Neste Meyer</td>
<td>V</td>
<td>Ratcliffe</td>
<td>6,307</td>
<td>2,307</td>
<td>0</td>
</tr>
</tbody>
</table>

(1) currently producing  
(2) shut in  
I/P = initial production  
H = horizontal, V = vertical, V/H = vertical recompleted to horizontal
Table 5. Selected wells in 36N – 58E, sections 19, 20, 28, 29, 30, 31 and 32.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Well Name</th>
<th>Well Type</th>
<th>Producing Formation</th>
<th>Formation Top (ft)</th>
<th>I/P Oil bbls/month</th>
<th>I/P Gas mcf/month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goose Lake</td>
<td>Reed (2)</td>
<td>V</td>
<td>Ratcliffe</td>
<td>6,801</td>
<td>323</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>A. Haugen(2)</td>
<td>V</td>
<td>Ratcliffe</td>
<td>6,805</td>
<td>480</td>
<td>131</td>
</tr>
<tr>
<td></td>
<td>Oska(2)</td>
<td>V</td>
<td>Ratcliffe</td>
<td>6,869</td>
<td>415</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Carl (2)</td>
<td>V</td>
<td>Ratcliffe</td>
<td>6,769</td>
<td>348</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>Goose Lake Deep 7-32</td>
<td>?</td>
<td>Red River</td>
<td>10,678</td>
<td>2,717</td>
<td>1,140</td>
</tr>
</tbody>
</table>

(1) currently producing
(2) shut in – these shut in wells were spudded in the mid to late 1960’s
I/P = initial production
H = horizontal, V = vertical, V/H = vertical recompleted to horizontal

Table 6. Selected wells in 36N – 58E, sections 19, 20, 28, 29, 30, 31 and 32. These wells were reentered and recompleted as horizontal wells. This recompletion of a vertical well resulted in increased production.

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Well Name</th>
<th>Well Type</th>
<th>Producing Formation</th>
<th>Formation Top (ft)</th>
<th>RE - I/P Oil bbls/month</th>
<th>RE - I/P Gas mcf/month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goose Lake</td>
<td>Hammer 1H-RE</td>
<td>V/H</td>
<td>Ratcliffe</td>
<td>6,736</td>
<td>1,178</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Keldsen 2H-RE</td>
<td>V/H</td>
<td>Ratcliffe</td>
<td>6,757</td>
<td>195</td>
<td>0</td>
</tr>
</tbody>
</table>

(1) currently producing
Wells were initially spudded in the mid to late 1960’s
RE - I/P = reentry and recompletion initial production
H = horizontal, V = vertical, V/H = vertical recompleted to horizontal
2. Hydrocarbon potential for the Bakken, Three Forks and Birdbear (Nisku) formations beneath land leased by Stratex Oil and Gas in Sheridan County, Mt.

Several Bakken and Birdbear (Nisku) wells in Sheridan County (T37N – R57E sections 9, 10 and 15) had very good initial production rates (Fig. 1) (Tables 1, 2 and 3). The Bakken formation in this area is similar to the Bakken in other areas of the Williston Basin, the upper and lower Bakken are made up of organic rich, dark grey to brownish black to black shales that are the source rocks, the middle Bakken is a highly variable in composition and is made up of light to medium gray siltstones and sandstones, silty dolostone and limestone and dark gray shale. The dolomitic sandstones and siltstones in the upper portion of the middle Bakken act as the reservoir rock for the oils generated in the black shales. The upper and lower Bakken black shales are thought to have been deposited in deep water with a stratified water column that had a well oxygenated upper portion and an anoxic lower portion. Organic material produced in the productive upper portion of this water column would have been preserved after it was buried in the anoxic deepwater sediments. The upper Bakken is approximately 10 feet thick where Stratex Oil and Gas has leased land in Sheridan County (Figs. 3). The lower Bakken is approximately 20 feet thick where Stratex Oil and Gas has leased land in Sheridan County (Figs. 4). The middle Bakken is approximately 50 feet thick where Stratex Oil and Gas has leased land in Sheridan County (Figs. 5). The upper portion of the middle Bakken has cross-stratified sandstones, indicative of a higher energy, shallow water depositional environment.

The middle Bakken (reservoir) has experienced multiple depositional and diagenetic changes that affect both the porosity and permeability of this unit and the ability of the Bakken to act as an oil producing system. An important event that affected the thickness of the Bakken was the dissolution of the Prairie salts. Dissolution of the...
Prairie salts occurred multiple times during the Paleozoic and Mesozoic. Dissolution collapses that occurred in a northeast-southwest trend through Canada and into northeastern Montana during middle Bakken deposition created accommodation space that resulted in a thicker middle Bakken in this area (Figs. 5, 6 and 7). In addition to creating accommodation space, dissolution collapses created faults and fractures that can act as conduits for the migration of oil between vertical formations, as well as along this fracture trend (Fig. 8).
Fig. 3. Isopach map of the upper Bakken. The upper Bakken is approximately 10 feet (3 meters) thick in eastern Sheridan County, where Stratex Oil and Gas has leased land. Stratex land is within the enclosing box, see figure 1 for the exact location of the land.

Fig. 4. Isopach map of the lower Bakken. The lower Bakken is approximately 20 feet (6.5 meters) thick in eastern Sheridan County, where Stratex Oil and Gas has leased land. Stratex land is within the enclosing box, see figure 1 for the exact location of the land.

Fig. 5. Isopach map of the middle Bakken. The middle Bakken is approximately 50 feet (16 meters) thick in eastern Sheridan County, where Stratex Oil and Gas has leased land. Stratex land is within the enclosing box, see figure 1 for the exact location of the land. The thickening trend in the middle Bakken is the Torquay-Rocanville trend. This occurred as a result of the dissolution of the underlying Prairie evaporite, which created accommodation space for middle Bakken sediments. See figure 6 for Prairie salt isopach.

Fig. 6. Isopach map of the Prairie Salt beneath Montana, North Dakota and Canada. The truncation in the 300 foot contour line was the result of localized dissolution of the salt. Dissolution of salt created accommodation space for additional middle Bakken sediments, see figure 5 for middle Bakken isopach thickening in this same location. This created the Torquay-Rocanville trend, see figure 7 for full extent of this trend. Multiple episodes of collapsing also created faults and fractures of the formation above the evaporites, including the Birdbear, Three Forks and Bakken formation and the overlying Madison Group, see figure 8 for seismic line showing collapse related faulting.

Source: Gerhard, 1982.
Fig. 7. Map showing the locations of major structural features and the oil discoveries in the Bakken formation and Madison Group in the Williston Basin. TRT = Torquay-Rocanville trend; BFL = Brockton-Froid lineament; MFS = Mondak fracture system. N1, N2 and N3 are the locations of three Bakken sourced Nisku (Birdbear) oils from Jarvie (2001). Dissolution of the Prairie salts lead to thicker middle Bakken deposits. Dissolution of the Prairie salts also resulted in faulting and fracturing in the formations above it, which created conduits for the upward migration of Bakken oil. In Canada, this allowed Bakken oils to mix with Lodgepole oils before migrating into the overlying Madison Group reservoirs.

More recent faulting extends from the Prairie salt to the formation that was being deposited at the time faulting occurred.

Dissolution collapses lead to the thickening of the overlying formations.

Faulting that occurred during the deposition of the middle Bakken extends from the Prairie salt to the middle Bakken, but does not pass through it.

**Fig. 8.** A seismic line showing a localized collapse feature due to the dissolution of the Prairie Salt in Southern Saskatchewan, Canada. Notice that some of the faults (green lines) extend vertically upward through multiple formations, including the Bakken shale, whereas others stop at the Bakken. The faults that stop at the Bakken occurred during Bakken deposition whereas the faults that pass through the Bakken occurred more recently. The fault and fracture zones that pass through the Bakken and into younger strata can act as conduits for the vertical migration of oil upward and out of the Bakken. Faults that extend up to, but not above the Bakken can act as downward conduits for Bakken oil migration. Collapses that occur during Bakken deposition also form accommodation space for thicker Bakken sedimentation.

The timing of these collapses is very important when considering the migration of Bakken sourced oils into other formations. It is well established that the Bakken is overpressured in the Williston Basin as a result of hydrocarbon generation. Where overpressure conditions exist, hydrocarbons are expelled downward because of pressure seals and gradients unless fault zones are present, which would allow for the upward migration of hydrocarbons. As a result of this overpressured condition, the upper Bakken has charged the middle Bakken with hydrocarbons and the lower Bakken has charged the underlying Three Forks and Birdbear (Nisku) formations. As stated above, a significant amount of dissolution of the Prairie salts occurred during the deposition of the middle Bakken, resulting in a thicker middle Bakken along the northeast-southwest Torquay-Rocanville trend (Figs. 5, 6 and 7). Vertical faulting and fracturing from the Prairie salt up to, but not above, the middle Bakken will aid in the downward migration of hydrocarbons into the Three Forks and Birdbear (Nisku) formations, which are directly below the lower Bakken and above the Prairie salt (Fig. 8). These faults and fractures will not only aid in the downward expulsion of hydrocarbons to porous zones within these formations, but will help to increase the permeability of these formations. This may be the reason for the good initial production rates of the Birdbear (Nisku) wells in Sheridan County, Mt. where Stratex Oil and Gas has leased land (Tables 1, 2 and 3).

Jarvie (2001) did an extensive geochemical analysis of the oils in the Williston Basin and determined that three Nisku (Birdbear) formation oils from Roosevelt County, Montana, were sourced from the Bakken formation and not the Duperow formation, which is directly below the Nisku (Fig. 7). Jarvie (2001) also indicated that, except for highly faulted areas, the Bakken and Madison oils were chemically distinct from each other throughout most of the Williston basin and concluded that mixing of oils does not occur extensively in the United States Williston Basin. Conversely, the fault and fracture zones that pass through the Bakken and into younger strata act as conduits for the vertical migration of oil upward and out of the Bakken and into the younger formations. Chen, et al, (2009) indicated that mixed Bakken and Lodgepole formations oils were the primary source of oil for the Madison reservoirs in the Torquay-Rocanville trend in Canada. This strengthens the role that faults and fractures from Prairie salt collapses have on oil migration in the Torquay-Rocanville trend, where Stratex Oil and Gas has leased land in Sheridan County, Montana.
The work of Chen, et al (2009) and Jarvie (2001) would suggest that development of the middle Bakken and underlying Three Forks and Nisku (Birdbear) formations may be better realized where faulting, due to Prairie salt dissolution collapses, has occurred during middle Bakken deposition, but not after.

Natural fracturing plays an important role in the successful development of Bakken wells in the Williston Basin, since they increase permeability in a low permeability formation. These natural fractures occur as a result of tectonic activity, the generation of hydrocarbons and from the regional stress field. As stated above, the dissolution and collapse of the Prairie salt has resulted in faulting and fracturing. The generation of hydrocarbons creates horizontal fractures within the Bakken, which increase in concentration, density and vertical distribution as thermal maturation and hydrocarbon generation increases. These horizontal fractures are the fractures that contain most of the oil in the middle Bakken. In addition, the middle Bakken reservoir typically has more fractures when in contact with thicker mature shales than when in contact with thinner mature shales. Finally, the regional stress field in this area has produced regional fractures with a predominant northeast-southwest orientation.

In addition to natural fracturing, porosity and permeability are affected by diagenetic changes and the mineral content of the Bakken formation. Enhancing porosity and permeability are the dolomitization of limestone sediments and the dissolution of carbonate minerals by the action of organic acids that form during the creation of hydrocarbons. In the Elm Coulee field in Richland County, Montana (to the south of Sheridan County) the intervals within the middle Bakken that have the highest percentage of dolomite and the lowest percentages of clay and calcite make the best reservoir targets. The reservoir in the middle Bakken is thought to be a dolomitized carbonate shoal. Cross stratified sandy intervals suggest strong current action, which would also have limited the deposition of fine grained material (clay) which would have lowered the overall porosity of the middle Bakken. The main types of porosity are
intercrystalline, intergranular, and secondary porosity due to dolomite dissolution. Dolomite dissolution is the result of the reaction between the dolomites and organic acids that are released by the thermal maturation of the shales. Sonnenberg and Pramudito (2009) indicated that fracturing was only a modest factor in the Elm Coulee field in Richland, Montana and that diagenesis was a more important factor increasing the permeability of the middle Bakken reservoir.

The diagenetic changes that can impede production need to be considered as well. These changes include mechanical compaction; the presence of clay minerals and the precipitation of both early (dolospar and calcite) stage and late stage (ferroan dolomite and authigenic K-feldspar) cements. These changes have reduced the porosity of the middle Bakken to between 1% and 16% (averages 5%) and reduced the permeability to between 0 and 20 millidarcies (averages 0.04 millidarcies). This reduced porosity and permeability is the reason hydraulic fracturing is needed to make production from these wells economical.
3. Thermal Maturity of the Bakken in Sheridan County, Montana

As oils are produced in the thermally Bakken shales they displace an ever increasing amount of saline formation water in the pore spaces within the shale. Oils are poor conductors of electricity, whereas saline formation waters are excellent conductors of electricity. As a result, the resistivity of the shale increases with increasing amounts of oil in the pore spaces of the shale. Hydrocarbon generation within the Bakken shale produced resistivity values that range from approximately 25 to 100 ohm-m in value (Fig. 9). Resistivity values within the Bakken shales beneath the land leased by Stratex Oil and Gas are approximately in the 40 to 100 ohm-m range, indicating that these shales have produced oil (Fig. 10). Oil production from wells surrounding the land leased by Stratex Oil and Gas is consistent with the above and a confirmation of the validity of the resistivity contour map in determining if oil is present in the pore spaces of the Bakken shale.

Kreis, et al (2006) cautioned that resistivity values should not be the only criteria used for evaluating the hydrocarbon prospects of the middle Bakken due to the presence of low-resistivity pay zones in that unit. These are zones that produce oil, but show low resistivity values in well logs. Kreis, et al (2006) gave two examples of vertical wells in the middle Bakken in Southeastern Saskatchewan that produced oil from zones that had resistivity values in the 3 to 4 ...
Fig. 9. Hydrocarbon generation in the Bakken shale produces resistivity values that range from approximately 25 to 100 ohm-m in value. Resistivity values within the Bakken shales beneath the land leased by Stratex Oil and Gas are approximately in the 40 to 100 ohm-m range, indicating that these shales have produced hydrocarbons (see Fig. 10).

Fig. 10. The resistivity contour lines for the lower Bakken range in value from approximately 40 to 100 ohm-m where Stratex Oil and Gas has its land. These levels of resistivity indicate that the Bakken is mature in this area (see Fig. 9). Resistivity values increase toward the center of the basin.

ohm range. Reservoirs with laminated sandstone and shales, fined grained sandstones, conductive minerals, fresh water and microporosity can have low-resistivity pay zones. The middle Bakken sandstone reservoirs have many of these traits (fine sandstone interlaminated with argillaceous layers and abundant pyrite) which all act to lower the resistivity of these fine grained sandstones.
4. Hydrocarbon Potential of the Three Forks Formation

The Three Forks formation is directly below the Bakken shale in the Williston basin, the contact between the two formations is an unconformity surface. The Three Forks is approximately 150 feet thick in Sheridan County where Stratex Oil and Gas has leased land (Fig. 11). The Three Forks formation was deposited during a cyclical series of transgressions and regressions that deposited shale, anhydrite, dolomitic mudstones and siltstones, dolostone and dolomitic sandstone. The Three Forks formation is divided up into 6 units in North Dakota and Montana and 4 units in Canada. The lower portion of the Three Forks was deposited in a well oxygenated, arid, restrictive marine, or sabka environment as evidenced by red to tan shales, anhydrite and dolomite. The upper portion of the Three Forks represents a transgressive depositional environment which contains massive to chaotically bedded dolostone, dolostone interbedded with mudstones, bioturbated dolostone and sandstone (Fig. 12). The upper Three Forks in Sheridan County is approximately 10 feet thick where Stratex Oil and Gas has leased land.

Intraformational breccias and soil horizons are common in the Three Forks and indicate that periods of subaerial weathering occurred. Subaerial weathering can lead to the development of karst topography in carbonate and mixed carbonate rocks due to the dissolution of carbonate rocks by meteoric waters. This creates vuggy and intracrystalline porosity, solution enlarged fractures, caverns and solution collapse breccias where caverns have collapsed. There was a period of subaerial exposure at the end of the Three Forks depositional period that may have allowed for considerable karst development in the dolostone sections of the upper Three Forks before the rise in sea level that lead to the deposition of the Bakken formation (Fig. 12).
Fig. 11. Isopach map for the Three Forks formation in the Williston Basin. The Three Forks is approximately 150 feet thick in Sheridan County, Montana, where Stratex Oil and Gas have leased land.

Fig. 12. The upper Three Forks is made up of brecciated dolomites, which may be solution collapse features due to karst diagenesis. The Spanish Sand is a target for hydrocarbon production in North Dakota.

Many hydrocarbon reservoirs in North America are found in carbonate breccias that formed as a result of the collapse of karst caverns. Examples of carbonate breccia reservoirs are the Ellenburger Group carbonates in West Texas, the Arbuckle Group dolomites in eastern Oklahoma, the Arbuckle Group dolomites in Kansas and the Beekmantown Group carbonates in eastern Ohio. Caves, collapse breccias, solution enlarged fractures and vuggy, moldic and intercrystalline porosity, due to meteoric diagenesis, all contribute to the quality of the reservoir within these reservoirs. The Torquay (Three Forks) formation in Saskatchewan and Western Manitoba has had good production from brecciated intervals, indicating that meteoric diagenesis has contributed to the quality of these reservoir rocks in Canada.

The upper Three Forks generally has poor reservoir quality rocks. Porosity is in the 6 to 10% range and permeability is usually less than 0.1 millidarcies. In North Dakota, good success has been achieved using horizontal drilling and hydraulic fracturing. The lower Bakken, which lies on top of the Three Forks unconformity surface, is the source rock for the Three Forks. Zones of enhanced porosity zones can extend vertically downward 20 to 30 feet beneath unconformity surfaces in carbonate rich reservoir rocks (Fig. 13). As mentioned above, there are multiple unconformity surfaces in the Three Forks formation. Porous zones beneath these unconformity surfaces would make excellent exploration targets for Bakken sourced oils that have migrated vertically downward through fractures in the Three Forks. Along the Saskatchewan-Manitoba border, a major regional oil accumulation has developed as a result of enhanced reservoir porosity, due to meteoric diagenesis, immediately below the unconformity surface there. It is very possible that similar oil accumulations are in the Three Forks beneath Sheridan County, as well. An extensive fracture network through the Three Forks may exist, not only from collapses within the formation, but also from the collapse of the dissolution caverns that formed in the underlying Prairie salts along the Torquay-Rocanville trend (Fig. 7). This fracture network may have enhanced both the reservoir quality of the Three Forks formation and the ability of the oil to migrate into Three Forks reservoirs from the lower Bakken source rock making it an attractive exploration target in Sheridan County. At this time, the Three Forks does not appear to be producing oil where Stratex Oil and Gas has leased land in Sheridan County.
Figure 13. A comparison between the porosity profiles found in the Beekmantown dolomite from Beekmantown, New York (A) and the Beekmantown dolomites of eastern Ohio (B). Note that the porosity profiles are almost identical for the top 17 meters of core. Porosity is enhanced due to meteoric diagenesis, which dissolves carbonate minerals creating vuggy and intercrystalline porosity as well as solution enhanced fractures and solution collapse breccias. Similar porosity profiles may be present in the Three Forks formation below unconformity surfaces both within and on top of that formation.

Source: Clark and Friedman (2008).
5. Hydrocarbon Potential of the Birdbear formation

The Birdbear (Nisku) formation lies directly below the Three Forks formation in the Williston Basin. The lower part of the Birdbear was deposited as platform carbonates and is made up of 30 to 40 feet of shallow water, burrow mottled, calcareous (limestone and dolostone) mudstones and wackestones that contain abundant fossils (brachiopods, gastropods and rugose corals). The upper Birdbear is made up of several depositional cycles of dolostone and anhydrite in an intertidal and onshore, arid depositional environment. The upper portion of the Birdbear is commonly referred to as the A zone, whereas the lower portion is referred to as the B zone. The platform carbonates are overlain by a biohermal facies that is primarily made up of dolomitized stromatoporoids. Porosity in the bioherms ranges from 6% to 19%, permeability in the bioherms is up to 237 millidarcies.

Historically, production has come from the B zone where the B zone overlies structural highs and the B zone is overlain by anhydrites of the A zone which act as a caprock and from dolomitized stromatoporoid biostromes and bioherms (Fig. 14). The structural highs and traps in the B zone are the result of the multistage dissolution and collapse of caverns in the underlying Prairie salts. The first stage of dissolution of the Prairie salt lead to localized collapses and the formation of sink holes in northeastern Montana (Fig. 15a). The accommodation space that was created from the formation of these sink holes was filled in with the carbonates from the Souris River formation (Fig. 15b). Later stages of dissolution of the Prairie salts lead to the formation of steep sided, flat topped structures over the original sink holes that were filled in with Souris River carbonates (Fig. 15c). These structural highs are steep sided, typically less than a mile in diameter and form the Nisku B zone reservoirs in northeastern Montana. Production from the B zone comes from a pay zone 8 to 20 feet thick where the porosity is approximately 16% and permeability ranges between 4 and 10 millidarcies. Along the east flank of the Williston Basin, Birdbear production from the B zone occurs along structural highs that are updip from prominent synclines that formed as a result of dissolution and collapse of the Prairie salts. This indicates that there are several different types of structural plays in the Williston basin as a result of Prairie salt dissolution collapses. The Birdbear B zone, updip from synclines, may be targets in eastern Sheridan County where Stratex Oil and Gas has leased land.
**Fig. 14.** Pay zones in the Birdbear formation. The pay zone in the upper A zone is commonly in the second cycle, which is approximately 2 to 4 feet thick and is found in porous dolostones that pinch out within overlying and underlying anhydrite beds. The pay zone in the B zone is 8 to 20 feet thick and found where the Birdbear overlies structural highs.

**Fig. 15a.** The first stage of dissolution of the Prairie salt, possibly due to fluid intrusion through basement faults. Dissolution collapses lead to the formation of sink holes. Dbd = Devonian Dawson Bay formation; Dpe = Devonian Prairie evaporite formation; Dw = Devonian Winnipegosis formation; Si = Silurian Interlake formation


**Fig. 15b.** Accommodation space from the sink hole is filled in with carbonates from the Souris River formation. Dtf = Three Forks formation; Dn = Nisku formation; Dsr = Souris River formation; Dbd = Devonian Dawson Bay formation; Dpe = Devonian Prairie evaporite formation; Dw = Devonian Winnipegosis formation; Si = Silurian Interlake formation

Fig. 15c. Later stages of dissolution of the Prairie salts leads to the formation of steep sided, flat topped structures over the original sink hole that was filled in with Souris River carbonates. These structural highs are typically less than a mile in diameter and form the Nisku reservoirs in northeastern Montana. Dn = Nisku formation; Dsr = Souris River formation; Dbd = Devonian Dawson Bay formation; Dpe = Devonian Prairie evaporite formation; Dw = Devonian Winnipegosis formation; Si = Silurian Interlake formation

Recent exploration within the Birdbear has concentrated on the A zone, using horizontal drilling techniques, along the Bicentennial-Beaver Creek-Roosevelt Trend in Billings, McKenzie and Golden Valley Counties, North Dakota, (Fig. 16). Production from the A zone comes from a 2 to 4 foot layer of porous dolostone (14% to 25% porosity and 4 to 30 millidarcy permeability) that pinches out between overlying and underlying anhydrite beds that act as a seal (Fig. 14). The middle cycle begins with a one foot black shale, that may act as the source rock, and ends with several feet of anhydrite. The porous dolostone that is sandwiched between these two layers often has greater than 75% oil saturation. Horizontal wells along this trend have had initial production rates of over 500 barrels a day and ultimate production estimates of 300,000 barrels of oil per well.

The upper Birdbear is also producing oil in Saskatchewan, Canada, using horizontal drilling technology (Fig. 17). Organic geochemical analyses have identified the Winnipegosis formation as the source of the oil in the Birdbear formation in Saskatchewan. This seemingly contradicts the findings of Jarvie (2001) who indicated that the Bakken was the source of the oils in the Birdbear in northeastern (Roosevelt County) Montana. This difference may be due to faulting in Saskatchewan (from the collapse of Prairie salt dissolution caverns) that has created conduits for the upward migration of oil from the Winnipegosis to the Nisku (Fig. 8) and due to the northeastern migration of oil from mature Winnipegosis source rocks in North Dakota into Saskatchewan. Yang (2010) indicated that a more recent organic geochemical analysis has pointed to an unknown source rock for oil found in the upper Birdbear. This unknown source rock may be the black shale in the upper Birdbear, identified by Sperr as a possible source rock for the Birdbear horizontal play along the Bicentennial-Beaver Creek-Roosevelt Trend in Billings, McKenzie and Golden Valley Counties, North Dakota.

The Birdbear may be a productive formation beneath the land leased by Stratex Oil and Gas in Sheridan County, Montana (Fig. 16).
Fig. 16. Birdbear wells along the Bicentennial-Beaver Creek-Roosevelt Trend (outlined in red) through Billings, McKenzie and Golden Valley Counties, North Dakota. Brown represents wells in the A zone, light blue represents wells in the B zone and purple represents wells in both the A zone and the B zone. The black dots represent show the locations of older Birdbear wells.

**Fig. 17.** Heavily oil stained dolostone from the upper Birdbear formation, Saskatchewan, Canada. Vuggy and fracture porosity is readily visible in this photo.

6. Summary

1) As in most of the Williston Basin, the Bakken shale in Sheridan County is made up of organic rich upper and lower units that act as source rock and a middle unit that acts as a reservoir unit. Production comes from dolomitic sandstones and siltstones from the upper section of the middle Bakken. Production from the middle Bakken close to the land leased by Stratex Oil and Gas suggests that the middle Bakken will be productive beneath their land.

2) Production from the middle Bakken in the Williston Basin is enhanced by natural fracturing. Natural fractures form due to regional stresses, tectonic forces and hydrocarbon production. Collapses within the Prairie salts beneath the Bakken, Three Forks and Birdbear (Nisku) formations beneath northeastern Montana strongly suggests that these formations will have a higher degree of fracturing than if dissolution collapses in the Prairie did not take place. This should aid production from these formations. Seismic work should be used to determine degree of faulting and fracturing beneath Stratex land in this area.

3) The dolomitization of a limestone carbonate shoal in the Elm Coulee field created porous zones of intercrystalline and intergranular porosity where the best oil production comes from. If any shoaling occurred during the deposition of the middle Bakken, where Stratex Oil and Gas has their land, it is very possible that the dolomitization of limestone sediments may have occurred there as well.

4) Diagenetic changes that can reduce porosity in the Bakken include the precipitation of early and late stage carbonate cements and the presence of authigenic clays. This
can act to decrease production, but the use of hydraulic fracturing can open up tight reservoirs if they exist.

5) Horizontal drilling and hydraulic fracturing will probably be needed to realize positive economic results from Bakken wells.

6) The resistivity of the lower Bakken shale in the area where Stratex Oil and Gas has leased land ranges from approximately 40 to 100 ohm-m. This is within the oil window for the Bakken as evidenced by oil production from the Bakken in this area.

7) Low resistivity zones within the middle Bakken may be related to the presence of conductive minerals, such as pyrite, and interlaminated fine grained sandstones and shales within the formation and not an indication of a lack of hydrocarbons.

8) The work of Jarvie (2001) indicated that the Birdbear oils in northeastern Montana were sourced from the lower Bakken formation. The migration of the oils from the lower Bakken to the Birdbear was due to overpressure in the Bakken which acted as a top seal preventing the upward migration of oil. The migration of the oil was assisted by the fractures that formed as a result of the dissolution and collapse of the Early Devonian Prairie salt.

9) Oils migrating from the lower Bakken to the Birdbear had to have passed through the Three Forks formation. Oil passing through the Three Forks should have been able to migrate into collapse breccias, porous sandstone layers and the porous zones that lie beneath unconformity surfaces in the Three Forks formation. At this time, the Three Forks does not appear to have been tested in the area where Stratex Oil and Gas have
leased land. The Three Forks formation is currently a successful target for oil production in North Dakota and should be a target in Sheridan County, Montana.

10) The timing of the Prairie salt collapses is very important when considering the hydrocarbon potential of the Bakken, Three Forks and Birdbear (Nisku formations). Faults that extend up to, but not through, the Bakken will enhance oil migration downward from the lower Bakken into the Three Forks and Birdbear formations. Faulting that passes upward and through the Bakken will enhance the upward migration of oil out of the Bakken. Exploration targets in the Three Forks and Birdbear formations should be where seismic work shows no faulting above the Bakken.

11) Meteoric diagenesis has contributed to the quality of the reservoir rock of the Torquay (Three Forks) formation in Saskatchewan and Western Manitoba, where good production has been realized from brecciated intervals. It is very possible that meteoric diagenesis has enhanced the quality of the reservoir rock in the Three Forks formation in Sheridan County as well.

12) At this time, the Three Forks does not appear to be producing oil where Stratex Oil and Gas has leased land in Sheridan County. I have not been able to determine yet whether this formation was actively targeted and tested as a hydrocarbon producing formation, or whether it was merely passed over in favor of other targets.

13) The Birdbear formation produces oil from both the A and B zones throughout much of the Williston Basin and may be productive beneath land leased by Stratex Oil and Gas in both Golden Valley, North Dakota and Sheridan County, Montana.
14) The source rock for the Birdbear formation is variable and dependent upon local geological conditions such as the degree of faulting, presence of anticlines and the presence of interformational organic black shale.

15) The B zone of the Birdbear is a structural play (structural highs over former sinkholes and the updip sections of synclines) due to the dissolution and collapse of the underlying Prairie salt. The A zone is a stratigraphic play with production coming from porous dolostone sandwiched between impermeable anhydrite beds.

16) Dolomitized stromatoporoid biostromes and bioherms have been successful targets of hydrocarbon exploration in Sheridan County in the past and may be important targets for Stratex Oil and Gas.

The Bakken and Birdbear (Nisku) formations in northeastern Sheridan County, Montana have been shown to be able to produce oil. At this time, it appears that these formations, as well as the Three Forks formation, have not been thoroughly tested beneath the land leased by Stratex Oil and Gas and further geologic investigations, including historical well log data and either new or reprocessed seismic data, may indicate that these formations can produce oil beneath Stratex land also.
7. References

Burke, R.B. and Sper, J.T., 2005, Birdbear Formation Lithofacies in West Central North Dakota: Some Characteristics and Insight. NDGS Newsletter vol. 33, no. 5. pgs. 1 – 5.


Sonnenberg, 2011, Petroleum Potential of the Upper Three Forks Formation, Williston Basin, USA, Search and Discovery article no. 110153

Sper, J.T., 2005, The upper Birdbear Formation (Nisku) of Western North Dakota: Another Emerging Williston Basin Horizontal Play. in Meeting Program 2005 RMS-AAPG.


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