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A supplement to *Oil and Gas Investor, E&P,* and *PipeLine and Gas Technology*

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Table of Contents

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DUO: Bakken Is "The Super Bowl" Of Oil

Continental Resources CEO Harold Hamm: "The Bakken is the Super Bowl of shale. It's a game-changer."

Cleveland Sands

Horizontal drilling in this tight-sands reservoir is quietly generating production and profits.

DUO 2010: Rockies Team with Tantalizing Oil-prone Shales

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Canada's Cardium Tight-Oil Play Springs to Life Again

Cardium horizontal wells have Bakken-like characteristics in terms of per-well expected rates of return and reserve potential.

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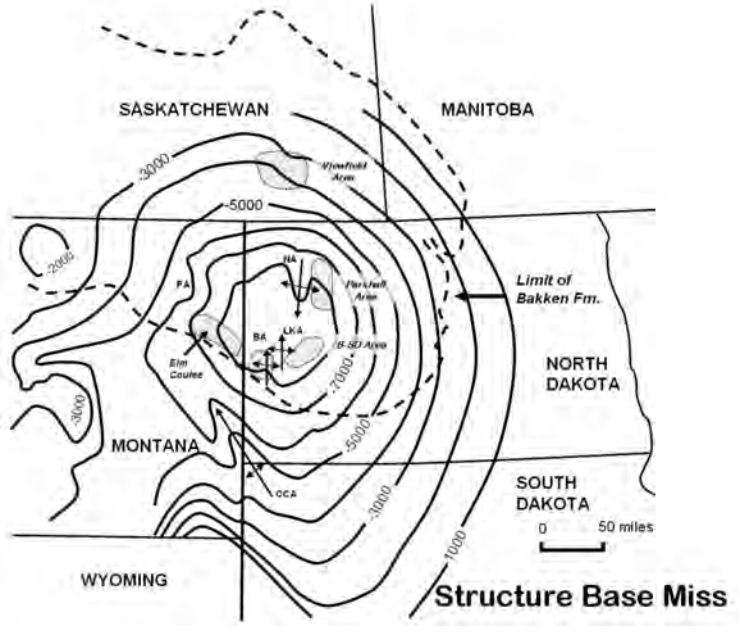
Focusing on the Bakken

The Bakken petroleum system in the Williston Basin is a tight oil resource play.

By Stephen A. Sonnenberg
Department of Geology, Colorado School of Mines

The Mississippian-Devonian Bakken petroleum system of the Williston Basin is characterized by low-porosity and permeability reservoirs, organic-rich source rocks, and regional hydrocarbon charge. The unconventional play is the current focus of exploration and development activity by many operators. Previous workers have described significant Bakken source rock potential, and estimates of oil generated from the petroleum system range from 10 to 400 Bbbl. The US Geological Survey (USGS) mean technologically recoverable resource estimates for the Bakken Formation are 3.65 Bbbl of oil, 1.85 Tcf of associated/dissolved natural gas, and 148 MMbbl of natural gas liquids.

The basin is semicircular in shape, and prominent structural features are the Nesson, Billings, Little Knife, and Cedar Creek anticlines. Many of the structural features have a documented ancestral origin and influenced Paleozoic sedimentary patterns. Recurrent movement on Precambrian faults or shear zones is seen elsewhere in the Rocky Mountain region. The Nesson Anticline is the location of the first oil discoveries in the 1950s. The first oil production on the Nesson Anticline was from the Silurian Interlake Formation in 1951 and subsequent oil production was established from the Mississippian Madison Group (the main producer in the basin). The Williston Basin produces mainly oil from several Paleozoic reservoirs.



Structure map on base of Mississippian. Contour interval is 1,000 ft. Prominent structural features in the Williston Basin include the Poplar (PA), Cedar Creek (CCA), Billings (BA), Little Knife (LKA), and Nesson (NA) anticlines. *(All images courtesy of the author unless otherwise noted.)*

The Bakken petroleum system consists of the Bakken Formation, Lower Lodgepole, and Upper Three Forks. A petroleum system consists of source beds and all the genetically related hydrocarbon accumulations. The Bakken Formation over most of the Williston Basin consists of three members: the upper shale; the middle silty dolostone or dolomitic siltstone and sandstone; and the lower shale.

The source beds for the petroleum system are the upper and lower organic-rich Bakken shales. The reservoir rocks for the petroleum system are all the members of the Bakken, the Lower Lodgepole, and the Upper Three Forks.

The Bakken petroleum system is thought to have created a continuous type of accumulation in the deeper parts of the Williston Basin. A continuous accumulation is a hydrocarbon accumulation that has some or all of the following characteristics:

- Pervasive hydrocarbon charge throughout a large area;
- No well-defined, oil- or gas-water contact;
- Diffuses boundaries;
- Commonly is abnormally pressured;

- Large in-place resource volume but low recovery factor;
- Little water production;
- Geologically controlled "sweet spots";
- Reservoirs commonly in close proximity to mature source rocks;
- Reservoirs have very low matrix permeabilities; and
- Water occurs updip from hydrocarbons.

The Bakken petroleum system meets all these characteristics.

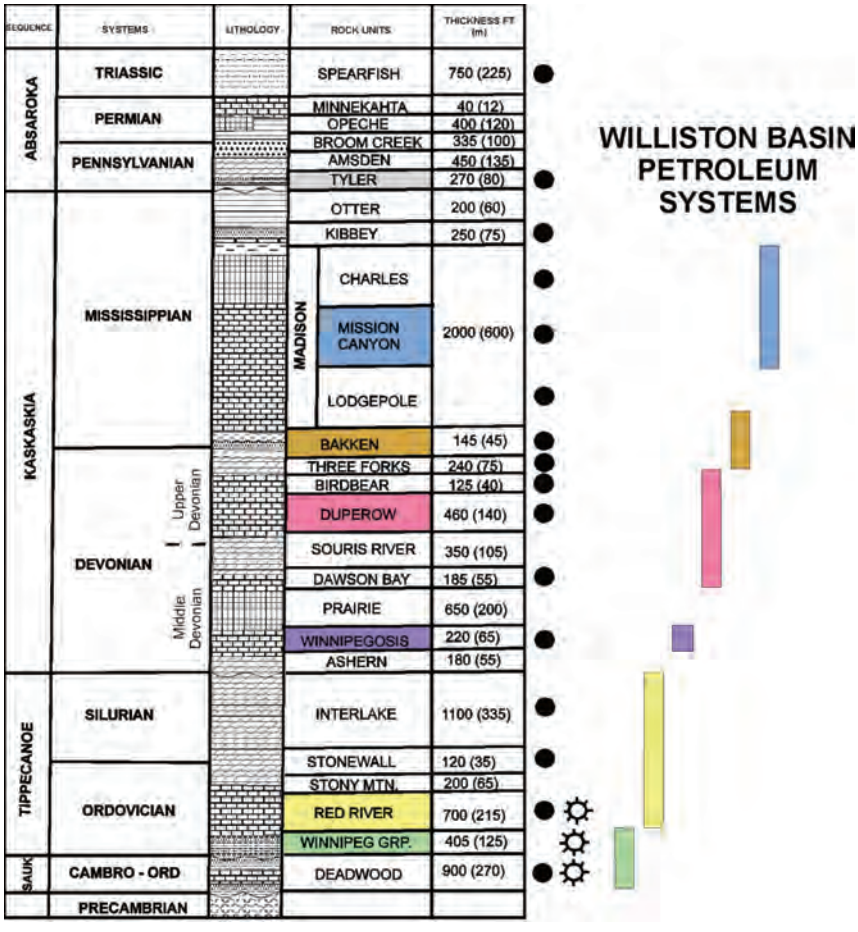
Many of the reservoirs in the Bakken petroleum system have low permeability. Productive areas, or "sweet spots," are localized areas of improved reservoir permeability through natural fracturing or development of matrix permeability, or a combination of both.

The Elm Coulee Field was discovered in 2000 with horizontal completions in the Middle Bakken. The field is located in the western part of the Williston Basin in northeast Montana. Prior to the horizontal drilling in 2000, the area had scattered vertical well production (marginal to uneconomic) from the Bakken; the Bakken was a secondary objective for wells targeting deeper horizons. Horizontal drilling began in the field in 2000 and, to date, over 600 wells have been drilled. The estimated ultimate recovery for the field is over 200 MMbbl of oil. Cumulative production from the Elm Coulee area from the Bakken to April 2010 is 98 MMbbl of oil and 74 Bcf of gas. Horizontal drilling and fracture stimulation of the horizontal leg are key technologies that enable a low-permeability reservoir to produce. Stratigraphic trapping plays a key role at Elm Coulee.

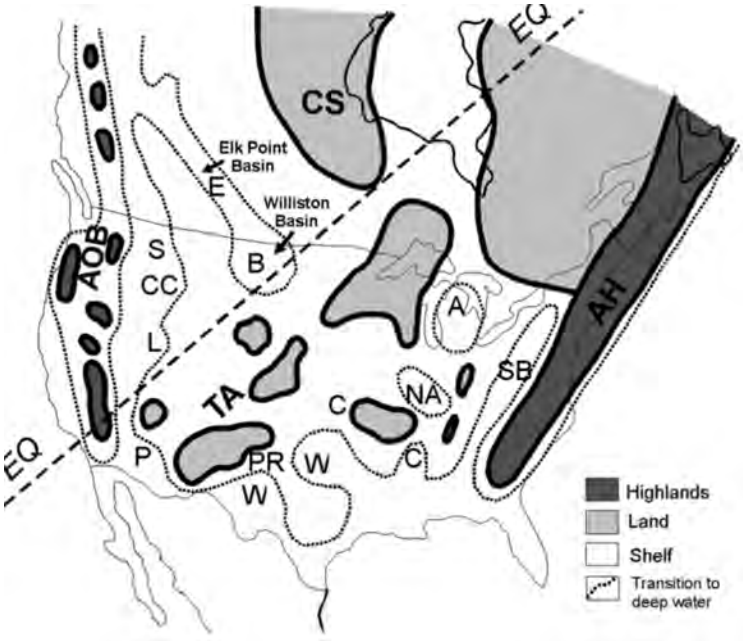
The Parshall Field, located on the east side of the Nesson Anticline, was discovered in 2006 with horizontal completion in the Middle Bakken. EOG Resources Inc. drilled and completed the 1-36 Parshall in section 36, T 150N, R90W for 463 b/d of oil and 128 Mcf/d of gas. Through April 2010, the field has produced approximately 32 MMbbl of oil and 13 Bcf of gas from 228 wells completed in the Bakken. This field illustrates that significant production from the Middle Bakken and Three Forks exists in North Dakota. The field connects to the Sanish Field to the west and the Ross Field to the north.

Regional geology

The Williston Basin is a large, intracratonic sedimentary basin that occupies parts of North Dakota, Montana, South Dakota, Saskatchewan, and Manitoba. The basin, however, probably originated as a craton-margin basin and evolved to an intracratonic basin during the Cordilleran orogen. Sedimentation occurred throughout much of the Phanerozoic and



Stratigraphic column for Paleozoic producing units in the Williston Basin. Producing units shown by oil and gas symbols. Sedimentary sequences are indicated. Thickness of stratigraphic units indicated in the column to the right (ft/m). Oil and gas symbols indicate producing formations. *Sources: Sloss (1963), LeFever (1992); Larry Anna/USGS (2009); and personal communication*



North America paleogeography and black shale deposits for Late Devonian, 360 Ma. Structural features: CS, Canadian shield; AOB, Antler Orogenic Belt; AH, Acadian Highlands; TA, Transcontinental Arch. Black shale deposits: B, Bakken; E, Exshaw; S, Sappington; CC, Cottonwood Canyon; L, Leatham; P, Pilot; PR, Percha; W, Woodford; C, Chattanooga; NA, New Albany; SB, Sunbury; A, Antrim. Position of equator marked by dashed line (EQ). Transition from shallow to deeper waters shown by dotted line. *(Source: Modified from Blakey, 2005)*

the thickness of the stratigraphic section is approximately 16,000 ft. Many unconformities are described in the stratigraphic section, but rocks of all of Phanerozoic time periods are represented by some deposits. Paleozoic strata consist mainly of cyclic carbonate deposits; the Mesozoic and Cenozoic strata consist mainly of siliciclastics.

During the Late Devonian and Early Mississippian, the basin was an area of active subsidence in a broad shelf area that existed along the western margin of North America. The proto-Williston Basin was an extension of the Devonian Elk Point Basin of Canada and situated in tropical regions near the equator.

Three Precambrian provinces underlie the Williston Basin: Superior craton, the Trans-Hudson orogenic belt, and the Wyoming craton. These provinces trend north to south and structures associated with them have strongly influenced later sedimentation and structural features. Notable structural features with a north grain in the Williston Basin include the Nesson, Billings, Little Knife, and Tree Top anticlines. Northwest-trending's prominent structural features include the Cedar Creek, Antelope, and Poplar anticlines. Periodically these structural features are reactivated through time.

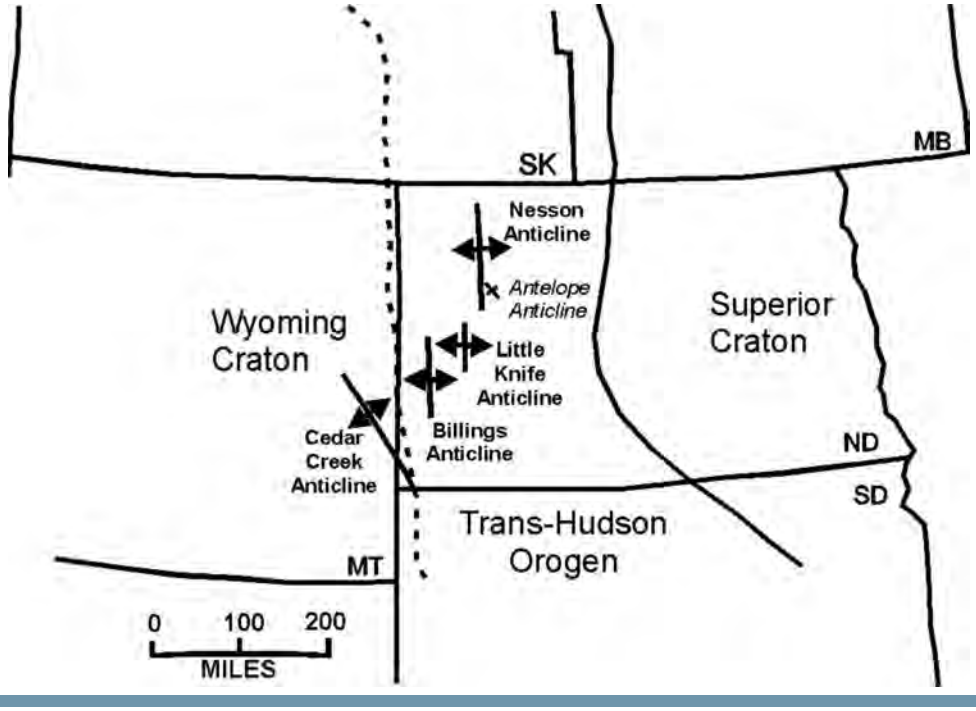
Bakken Formation geology

The Bakken Formation, regionally in the Williston Basin, consists of three members: upper and lower organic-rich black shale and a middle member (silty dolostone or limestone to sandstone lithology). The Bakken Formation ranges in thickness from a wedge edge to over 140 ft, with the thickest area in the Bakken located in northwest North Dakota, east of the Nesson Anticline. The three members of the Bakken thin and converge toward the margins of the Williston Basin and have an onlapping relationship with the underlying Three Forks. The contact between the Bakken and Three Forks is probably conformable in the deep parts of the basin and unconformable along the basin flanks. The Bakken is conformably overlain by the Lodgepole. The three members may represent two regressive-transgressive cycles of sedimentation. Following Three Forks deposition, major uplift and erosion occurred along the margins of the Williston Basin. With a subsequent relative sea-level rise and low-energy transgression, the Lower Bakken shales were deposited. Another regressive event resulted in the Middle Bakken being deposited, which was then followed by the next transgressive event that deposited the Upper Bakken shale.

The upper and lower shale members are potential source rocks and are lithologically similar throughout much of the basin. The shales are potential source beds for the Bakken, Three Forks, Lodgepole, and Mission Canyon formations. The shales are dark-gray to black, hard, siliceous, slightly calcareous, pyritic, massive to fissile, and generally either break along horizontal fractures or with conchoidal fractures. The shales contain radiolaria, conodonts, ostracodes, small cephalopods, small brachiopods, and Tasmanites (algae) fossils. The shales are dissimilar in that the upper shale lacks limestone and greenish-gray shale beds are found locally in the lower shale. Secondary pyrite occurs disseminated throughout the shale interval and as individual laminations and lenses. The shales consist of dark organic material, clay, silt-sized quartz, and some calcite and dolomite. The shale is kero-

gen-rich in the deeper parts of the basin and the organic material is distributed evenly throughout. The Bakken kerogen is an amorphous kerogen inferred to be sapropelic and the composition consists of 70% to 95% amorphous material, 0% to 20% herbaceous material, up to 30% coaly material (recycled opaque material), and 5% woody material. Research indicates the amorphous material has an algal origin because of the high hydrocarbon-generating capacity of the material determined from pyrolysis (greater than 500 mg HC/g OC at shallow depths). The total organic carbon content of the Bakken shales averages 11.3%. The upper and lower shale are interpreted to have been deposited in an offshore marine anoxic or oxygen restricted environment during periods of sea-level rise. The anoxic conditions may have resulted from a stratified hydrologic regime. The stratified water column is envisioned as having an upper water layer that is well oxygenated and nutrient rich. High organic production occurred in this layer (probably planktonic algae). With the death of the organisms, they sank through stagnant bottom waters and were deposited. Anoxic conditions are created by restricted circulation and in part by destruction of organic matter by consuming organisms that remove oxygen and release hydrogen sulfide. Anoxic conditions are indicated by the lack of benthic fauna and burrowing, and high TOC content. The Bakken may be part of continent-wide anoxic event that took place from Late Famennian through Kinderhookian time. The Bakken is correlative with the Woodford-Percha-Leatham-Sappington-Exshaw-Cottonwood Canyon source rock facies of the western Cordilleran and southern craton-margin geosynclines and the Antrim-Sunbury-New Albany-Chattanooga and equivalent source rock facies of the Appalachian geosyncline.

The Bakken is not thermally mature throughout the Williston Basin. The shales are thermally immature in the eastern part of the basin and characterized on well logs by low resistivity (i.e., water-wet). In the western Williston, the shales are characterized by high resistivity and thought to be oil-wet. Hydrocarbons are non-conductive, which results in the extremely high resistivities. Further evidence of the presence of hydrocarbon saturation comes from core analyses and also plots of pyrolysis data (i.e., production index vs. depth plots or pyrolysis S1 vs. depth plots) with depth. These data clearly indicate that the Bakken shales are oil-saturated where they have high resistivity. Wettability tests in the Bakken illustrate that the upper and lower shales are oil-wet while the Lodgepole, Middle Bakken, and Three Forks intervals are water-wet. Research has noted the extremely high oil-to-water ratios associated



Precambrian provinces underlying the Williston basin consist of the Superior craton, the Trans-Hudson orogen; and the Wyoming craton. Many of the prominent north-south structural features of the Williston Basin may be related to the Precambrian provinces (i.e., Billings, Little Knife, and Nesson anticlines).

with Bakken production, suggesting most of the water has been displaced by the hydrocarbon generation. The ratios are 200 to 800 to one with the mean being 300 to one. The small amount of co-produced water may be dissolved in Bakken oil, and exsolves during production, or it can be produced from matrix of the reservoir rocks.

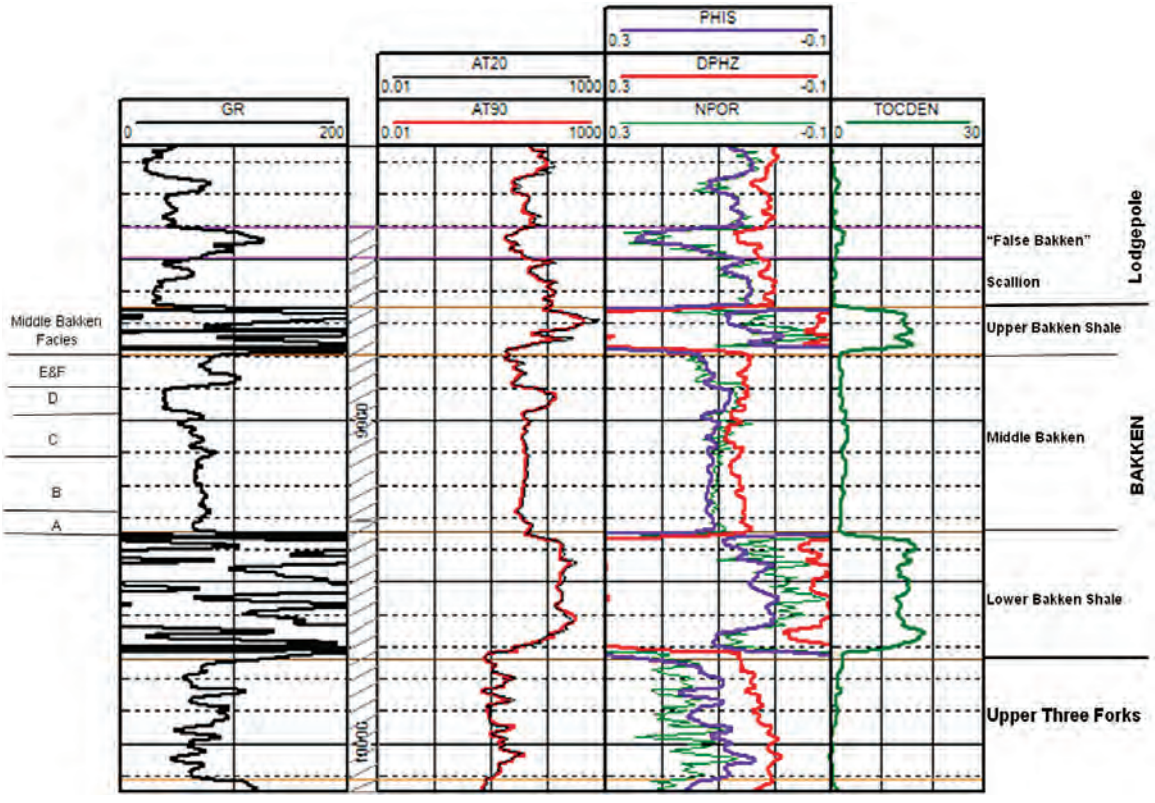
Organic maturity has recently been modeled using the Time-Temperature Index (TTI) method. The models suggest that organic maturity started approximately 100 Ma. Additional study suggests that hydrocarbon generation started in the early Cretaceous, and TTI plots were used to conclude that oil generation initiated approximately 75 Ma (late Cretaceous).

Most of the oil generated in the Bakken black shales may have been expelled into the middle member of the Bakken or the Upper Three Forks. There is also evidence that most of the oil generated in the Bakken stayed in the Bakken and did not migrate into the overlying Madison group. Earlier investigators thought the Bakken shales sourced reservoirs in the Bakken and entire Madison group.

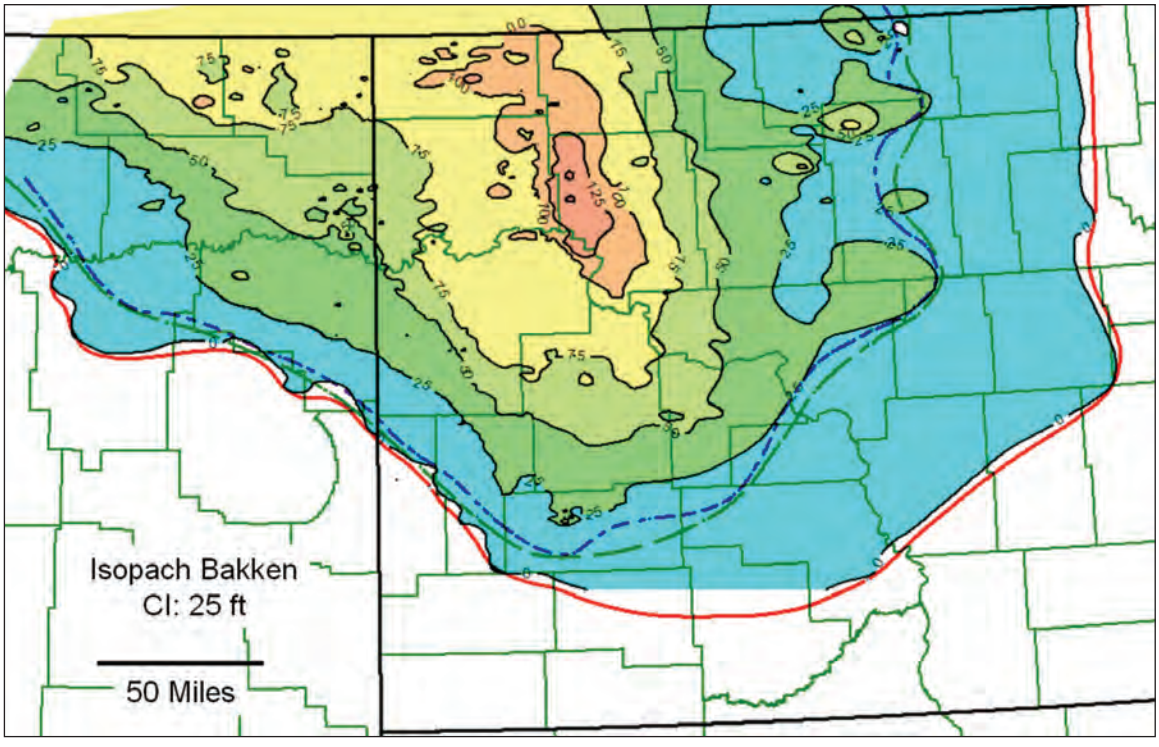
The middle member of the Bakken was deposited in a shallow-water setting following a rapid sea level drop, resulting in a regressive event. In the central part of the basin, the middle member consists of argillaceous, greenish-gray, highly fossiliferous, pyritic siltstones, which indicate an environment that was moderately well oxygenated but occasionally dysaerobic. The upper parts of the middle member have cross-stratified sandy intervals that suggest strong current action. The mineralogy of the Middle Bakken is variable across the basin and consists of 30% to 60% siliciclastic material (quartz and feldspar), 30% to 80% carbonate (calcite and dolomite), and minor matrix material (illite, smectite, chlorite, and kaolinite). The sources of the detrital fraction in the Middle Bakken are thought to be from the north and northwest.

The Middle Bakken can be subdivided into multiple facies. All the facies are thought to be shelf related and appear to represent a shallowing upward sequence followed by a water deepening event. The facies from bottom to top are:

- Facies A, a fossiliferous calcareous siltstone;



Well log display of the Bakken and Upper Three Forks from the Whiting Braaflat 11-11H (Sec. 11, T153N, R91W). Upper Bakken and Lower Bakken shales have very high GR readings (>200 API). Middle Bakken and Three Forks have low porosities (<10%). Middle Bakken can be subdivided into facies A-F. This well was completed in a horizontal leg for 2,669 b/d of oil. Headings: GR-gamma ray; AT 20 and AT90 resistivity curves; PHIS-sonic porosity; DPHZ-density porosity; NPOR-neutron porosity; TOCDEN-calculated TOC from density log.



The Bakken ranges in thickness from a wedge-edge to over 125 ft. The thickest area is just east of the Nesson Anticline. The limits of the upper shale is the heavy red line; the middle Bakken the dashed green line; the lower Bakken shale by the blue dashed line.

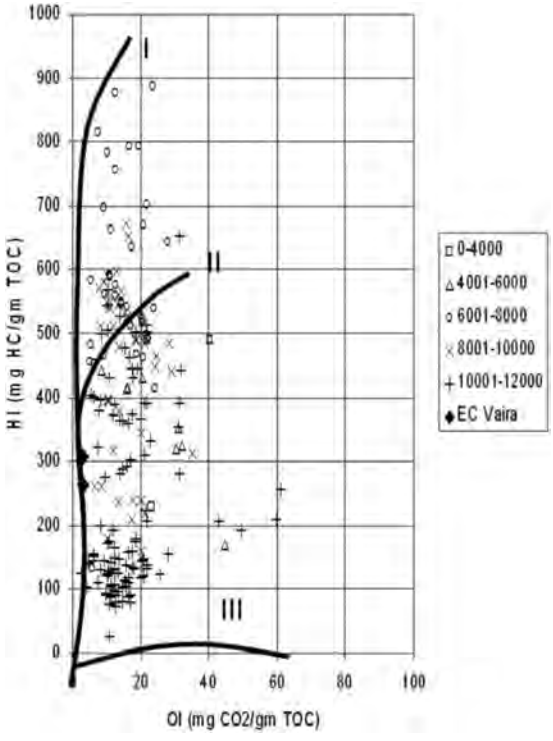
- Facies B, a bioturbated calcareous clay-rich siltstone to very fine-grained sandstone;
- Facies C, a thinly bedded to laminated calcareous very fine-grained sandstone;
- Facies D is the highest-energy facies and consists of fine-grained sandstone to carbonate grainstones;
- Facies E represents the start of the water deepening and consists of thinly bedded, occasionally microbial laminated, to parallel laminated siltstone; and
- Facies F consists of fossiliferous dolomitic to calcitic siltstone.

The facies are widespread across the Williston Basin with some exceptions. Facies D is only locally developed; the amount of dolomite changes from area to area; production is associated with matrix development in facies C, D, and E; and microfracturing. Facies B and C produce at Elm Coulee (Facies D is not present) whereas, facies C, D, and E produce in the Sanish-Parshall areas.

Thickness variations in the Bakken result from a variety of factors including varying depositional rates, paleostructures created by either basement fault movement or Devonian Prairie evaporite dissolution and onlap of units towards the basin edges. Structural features such as the Nesson Anticline have dramatically influenced Bakken depositional patterns and also influenced hydrocarbon migration. The thickest Bakken in the Williston Basin occurs just to the east of the Nesson Anticline. The thickening in this area occurs in all three members of the Bakken Formation.

The Devonian Prairie evaporite occurs about 800 to 1,100 ft beneath the Bakken Formation. Regional and local dissolution is known to have occurred in the Prairie. Dissolution occurs both as a roughly linear front and also in isolated semicircular areas. Dissolution of the Devonian Prairie evaporite occurred at multiple times during the Paleozoic and Mesozoic. Isopach thicks in formations above Prairie thin help document the timing of dissolution. Models suggested for salt dissolution include:

- Depositional facies control (dissolving fluids move through permeable beds adjacent to the salt horizon);
- Compaction and dewatering of surrounding sediments (supplies the fluid necessary for salt dissolution);
- Surface water recharge at the outcrop (resulting basinward flow dissolves salts); and



Modified van Krevelen diagram for the Bakken Formation of Williston Basin. Majority of samples indicate a Type-I and II oil-prone kerogen (algal origin). Legend shows source rock data by depth interval; EC Vaira from Elm Coulee (only 2 data points available). HI is hydrogen index (S2/TOC). OI is oxygen index (S3/TOC). *(Source: Webster, 1984, and Price et al, 1984)*

- Direct or indirect result from minor tectonic movement related to Precambrian basement features (e.g., faults create pathways for fluids). Dissolution of the prairie occurred during Bakken time and affected Bakken sediments.

Upper Three Forks Formation

The upper Three Forks is evolving into a significant resource play in the Williston Basin. To date, over 200 wells (including the older wells at Antelope) have been completed in the Upper Three Forks. The Upper Three Forks consists largely of silty dolostones that are interbedded with green chloritic mudstone. A variety of facies have been reported in the Upper Three Forks which range in depositional environment from subtidal to supratidal. Locally, a sandstone unit named the Sanish is present at the top of the Upper Three Forks. Debate exists whether the sandstone belongs in the Three Forks or if it is part of the Bakken Formation.

The Sanish and Upper Three Forks have low permeabilities and porosities. The original discovery at the Antelope Field in 1953 early on established the Sanish and Upper Three Forks as a viable reservoir in the Williston Basin. The Upper Three Forks remained fairly dormant until recently drilled horizontal wells again have indicated its large potential.

The North Dakota Industrial Commission (NDIC) has recently estimated the Three Forks will have recoverable reserves of 1.9 Bbbl of oil across much of the Williston Basin. The Three Forks play coincides with the Bakken play which adds significantly to the reserves across the basin.

Exploration history

The Bakken Formation of the Williston Basin has seen several cycles of exploration and development since the 1950s. The earliest discovery occurred in the Antelope Field of North Dakota in 1953 and development continued into the 1960s. Sixty-three wells targeted the Bakken and the Upper Three Forks (referred to as the Sanish member) on a tightly folded structure. The Bakken and the Upper Three Forks are low permeability, fracture-enhanced reservoirs in Antelope with fracturing related to the tight fold. The wells were drilled vertically, and after a sand-oil fracture stimulation treatment, were capable of producing an average of 209 b/d of oil. Antelope Field has produced 11 MMbbl of oil and 20 Bcf of gas from the Three Forks Bakken interval. Average cumulative production per Three Forks well is 550 MBO and 1.4 Bcf of gas. Following the Antelope discovery, exploration proceeded slowly. All three members of the Bakken and the Upper Three Forks were perforated in Antelope and production established these formations as petroleum reservoirs in the basin.

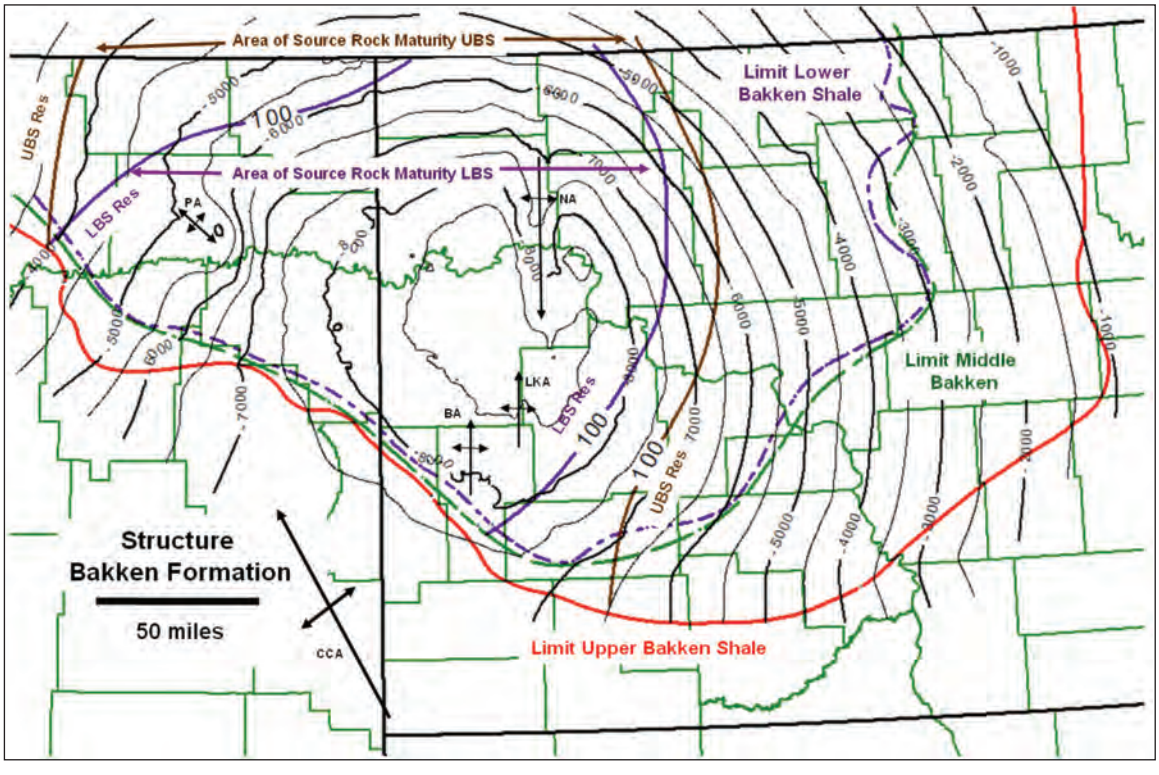
The next significant discovery in the Bakken was by Shell in the Elkhorn Ranch Field in 1961 in the Billings Nose area. The Upper Bakken Shale was completed in the well as a secondary objective after the deeper primary objective, the Red River zone (Ordovician), was not successful. The Elkhorn Ranch well was very significant in that it showed that significant reserves could be found in the Upper Bakken Shale. Because of product prices and remoteness of the area, the next Bakken well was not drilled until 1976. This area then became known as the "Bakken Fairway" area. Wells drilled in the fairway targeted the Upper Bakken Shale and other Paleozoic horizons (both shallower and deeper). The area occurs along the southwest margin of the

Bakken depositional basin in the general area of the Billings Nose. Where the Bakken thins, fracture density increases. Sand-oil fracture stimulation treatment was used on these wells.

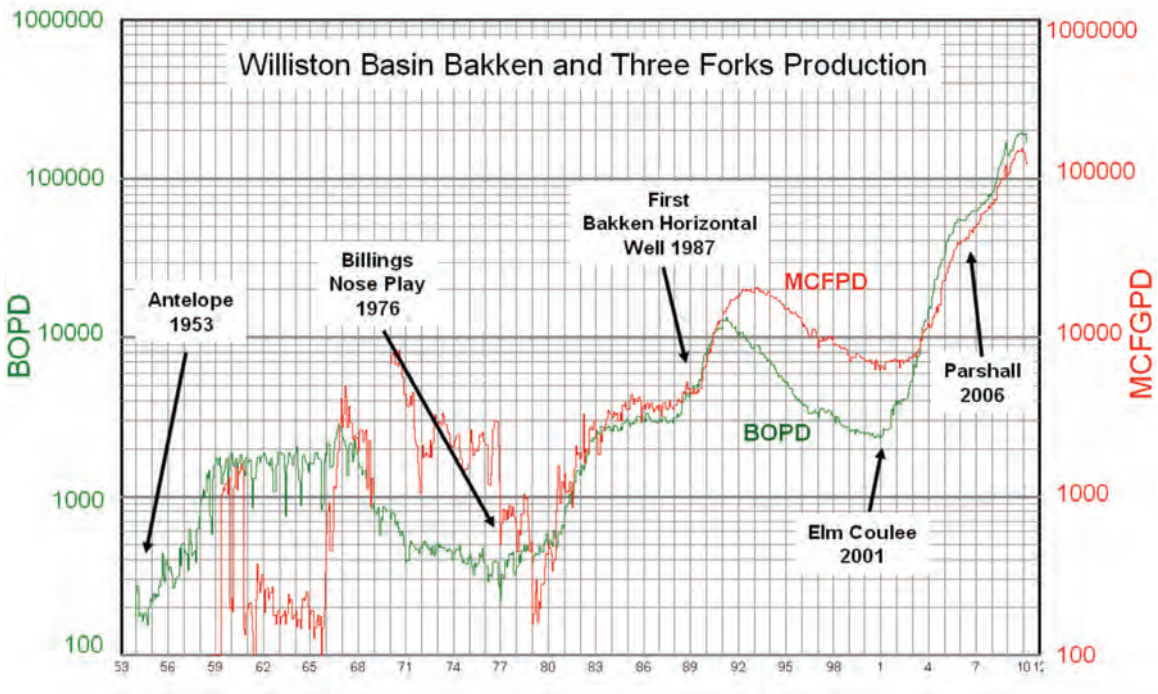
Horizontal drilling in the Upper Bakken Shale commenced in 1987 in the fairway area. The first horizontal well, drilled by Meridian Resource Corp., was the #33-11 MOI well (section 11, T143N, R102W, Elkhorn Ranch Field) which had a horizontal displacement of 2,603 ft in the Bakken. The well was completed for 258 b/d of oil and 299 Mcf/d and production was remarkably stable for the first two years. The success of this well set off the horizontal drilling phase of the Upper Bakken Shale. The play continued into the 1990s with over 20 operators. Product prices declined significantly in the 1990s, and along with the somewhat unpredictable production in the Upper Bakken Shale, brought this phase to a close. The fairway play met with mixed results. Good producing wells were often offset with poor producing wells. In addition, some pressure depletion and cross-well communication were reported.

Because of mixed results in the fairway trend and low product prices, the Bakken again returned to the status of being a secondary objective type of a reservoir rather than a primary objective of exploration. This status changed with the discovery of significant reserves in the Middle Bakken in the Elm Coulee Field. The discovery and development of the Middle Bakken have resulted in the most significant of the exploration cycles to date.

The Elm Coulee Field of Richland County, Mont., was discovered with horizontal drilling in 2000. The play was conceived by a Billings, Mont., independent, Dick Findley, who had noted mud log shows in the Middle Bakken while targeting deeper Nisku targets. The key well for identifying the potential in the Bakken was the Kelly/Prospector Albin FLB 2-33 well (section 33, T24N, R57E; Richland County). The well was drilled to test the Nisku and the deeper horizons did not work out, so the Bakken secondary objective was pursued. The 2-33 well was perforated in only the Middle Bakken because of the shows seen on the mud log (whereas the upper shale typically would be perforated as well). The well was treated with a water-sand fracture stimulation (instead of the more normal oil-frac) consisting of 80,260 gal of water and 151,800 lb of sand. The Middle Bakken flowed 157 bbl of



Structure map on top of Bakken and limits of Lower Bakken Shale, Middle Bakken, and Upper Bakken Shale across Williston Basin. Areas of source rock maturity for Upper Bakken Shale and Lower Bakken Shale are indicated by 100 ohm-m contour lines.

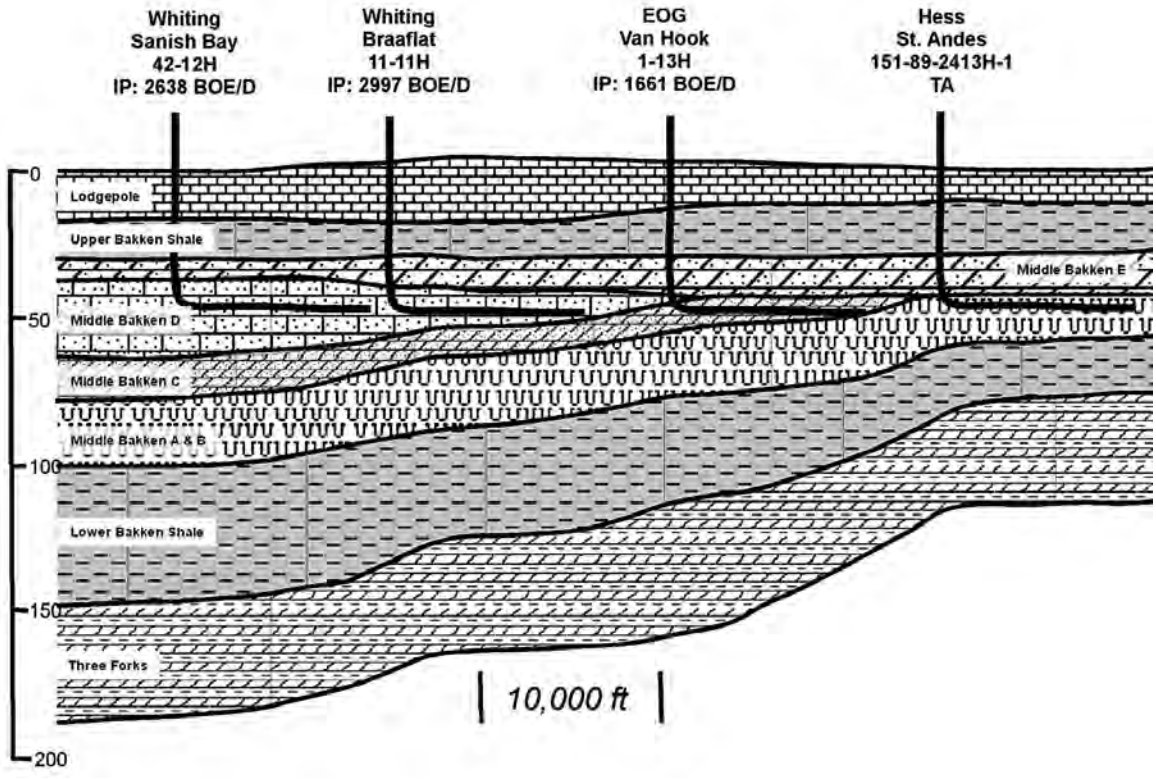


Production curve for the Bakken and Three Forks in the Williston. The Bakken and Three Forks have seen three significant cycles of development and the latest cycle is by far the most significant.

oil for the first 20 days beginning in March 1996, and was still making 80 b/d of oil after three months. The results of this well were very encouraging; thus, the concept was developed that a large field existed in the area that had previously been drilled through with more than 100 wells. An area four to five miles wide and 30 miles long was mapped out where the porosity development along with high resistivity was observed. Findley originally termed his prospective area "sleeping giant" because it had been drilled through many times. Several re-entries/recompletions were done in the late 1990s to pursue the play (the price of oil at the time the play developed was US $8/bbl). Horizontal drilling in the middle member started in 2000 which lead to the discovery and continuous development of the Elm Coulee Field. Individual horizontal wells are sand-water fracture stimulated and have initial production of 200 to 1,200 b/d of oil and estimated ultimate recoveries of 300,000 to 750,000 bbl of oil per well. The field is estimated to have an ultimate recovery of greater than 200 MMbbl of oil. Technology plays a very important role in this development with horizontal drilling and fracture stimulation.

The Elm Coulee discovery and development prompted operators to also target the Middle Bakken in North Dakota. Prior to Elm Coulee, most operators targeted only the upper shale in the Bakken. The expansion of the play into North Dakota is currently under way and has resulted in new discoveries including the Parshall and Sanish fields. Denver independent Michael Johnson is credited with recognizing the potential of the Parshall area, putting an acreage block together, and selling the prospect to EOG. EOG is credited, of course, with recognizing the potential of the area and drilling the discovery well. Whiting Petroleum Corp. geologist Orion Skinner is credited with recognizing the thick Bakken development in areas east of the Nesson Anticline and acquiring acreage in what turned out to be the Sanish Field (adjoins the Pashall Field). The new discoveries in North Dakota suggest the existence of an extremely large unconventional resource play. Product prices will probably influence this cycle too. Although regarded as a maturely drilled basin, the Williston continues to yield giant oil discoveries.

Horizontal wells in the Parshall-Sanish areas target specific facies (C, D, E) of the Middle Bakken. Production is related to fracture development and matrix development in the Middle Bakken. The original oil in place in the Parshall greater area is estimated by various operators to be 8 to 11 MMbbl per section for the Bakken



Stratigraphic cross-section across Sanish and Parshall fields. Horizontal wells target Middle Bakken facies C, D, and E facies. Stratigraphic thinning in the Middle Bakken contributes to the trapping mechanism for the field. Note how facies C and D pinch-out to the east. *{Source: Modified from Whiting, 2010)*

and 4 to 6 MMbbl per section for the Three Forks. Wells are drilled on either 1,280-acre spacing units or 640-acre spacing units. Estimated ultimate recoveries for the Bakken are 600 to 900,000 bbl of oil per section and estimated ultimate recoveries for the Three Forks are 350 to 500,000 bbl of oil per section. The recovery factor for the tight reservoirs is approximately 8%. Current well costs are in the $5 million to $6 million range. Because of high production rates, wells can pay out in four to six months. Some operators prefer the 1,280-acre spacing units over the 640-acre spacing units because of cost savings associated with the drilling of one well instead of two. Operators are fracture stimulating wells with 10 plus frac stages. On the west side of the Nesson Anticline, one operator is reported to have used 36 frac stages in an approximately 10,000 foot lateral.

Various methods have been proposed to explore for the Bakken. The methods include:

- Exploring along the depositional edge (more susceptible to fracturing and fracture spacing decreases as bed thickness decreases);
- Exploring structural flexures and lineaments;
- Looking for prairie dissolution areas as they may be areas of more intense fracturing;
- Looking for geothermal anomalies (intense hydrocarbon generation may cause more intense fracturing);
- Looking for primary reservoirs (i.e., Middle Bakken); and
- Looking for fractured areas identified by well logs.

The latest cycle of exploration and development in the Williston Basin is the most significant to date. Production for the US part of the Williston Basin has gone from 2,500 b/d of oil to close to 200,000 b/d of oil.

Petrophysical properties

The Lower Lodgepole, Bakken, and Upper Three Forks are easily recognized on wireline logs and the Bakken shales have unusual properties. The organic-rich shales in the Bakken have very high gamma-ray readings (greater than 200 API units); high deep lateral log (DLL) or induction log (DIL) resistivity in the thermally mature areas of the basin (low readings in thermally immature areas); high interval transit times (80 to 120 msec/ft) or

low sonic velocities; high neutron porosity; and low bulk density.

The Bakken shales average 11 wt.% TOC which, by volume, equals about 21.5% organic matter. The average TOC content represents the current organic content of the shales. Prior to maturation, the number was approximately 5 wt.% higher. An average of 16 wt.% TOC converts to 31 vol.% organic matter.

The very high gamma-ray readings are attributed to uranium, associated with the high organic matter content.

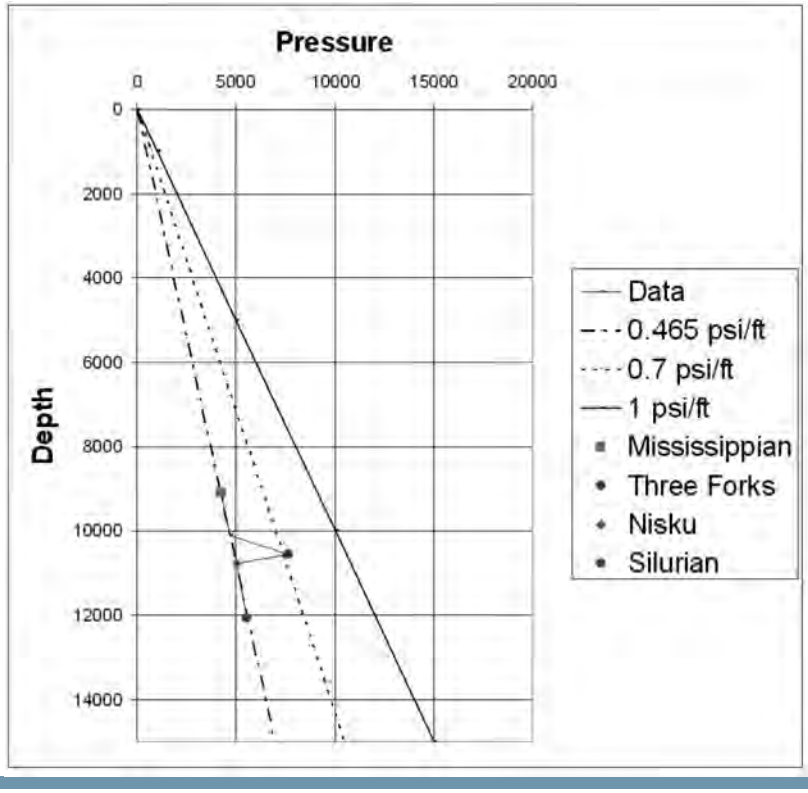
The low sound-velocity (high transit time) is believed to be due to high content of low-velocity organic material. An additional factor contributing to the high transit times is the high oil saturation in the shales. Sound velocities in oil are less than those in water and, thus, the replacement of water by oil in the Bakken source rocks leads to a diminishment of source-rock velocity. Microfracturing may also contribute to high transit time.

Shale formation density has been related to total organic carbon content. The high-density log porosity (low formation density) is due to the volume of organic matter present. The following equation is used for calculating TOC from bulk density: TOC = (154,497/ρ) – 57.261, where TOC is total organic carbon and ρ is the bulk density of the shale.

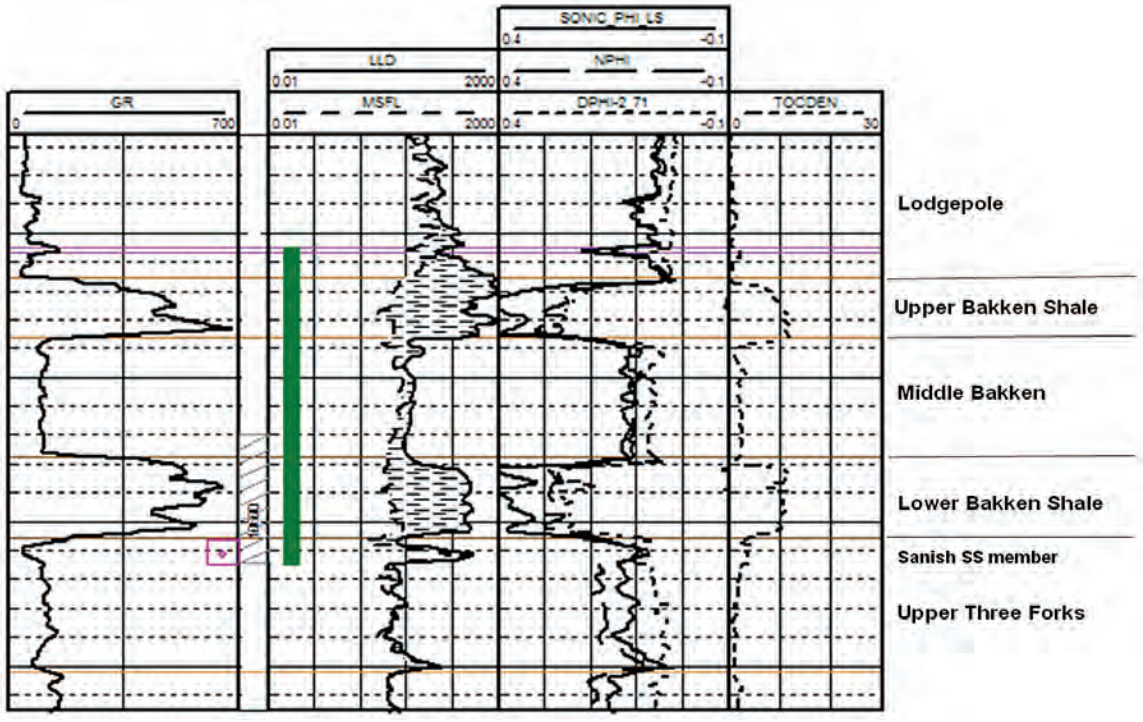
Reservoir properties

Measured core porosity and permeability are very low in the Bakken, Sanish, and Three Forks reservoirs (less than 10% porosity and less than 0.1 md permeability) in the Williston Basin, so productivity is assumed to be due to natural and artificial fracturing. The reservoirs generally require advanced technology to get them to produce (fracture stimulation and horizontal stimulation). For this reason they should be considered to be "technology reservoirs." Natural fractures in some areas (e.g., Billings Nose area and Antelope Field) are sufficient for vertical well production.

According to a core analysis from the Whiting Braaflat 11-11H (section 11, T153N, R91W), the Scallion member of the Lodgepole has an average porosity of 2.3% and average permeability of 0.12 md (most permeability plugs had visible fractures). Average grain density is 2.7 gm/cc. The Middle Bakken has average porosity of 6.7% and average permeability of 0.33 md (including plugs with visible fractures). Excluding core plugs with fractures, the average permeability number drops to 0.028 md. Average grain density in the Middle Bakken is 2.7 gm/cc. The Three Forks has an average porosity of 7.6% and average permeability of 1.1 md (including core plugs with visible fractures). The average permeability, excluding the plugs with fractures, is 0.23 md. Average grain density in the Three Forks is 2.8 gm/cc. Most of the visible fractures in the core are horizontal. The Braaflat 11-11H was completed as a horizontal well in the Middle Bakken for 2,669 b/d of oil and



Pressure depth plot for Antelope Field (modified from Murray, 1968; Meissner, 1978). The Three Forks is overpressured whereas, the formations above and below are all normally pressured.



Well log display of the Bakken and Upper Three Forks from the Duncan Rose #1 well, Antelope Field (Sec. 33, T152N, R94W). Logs include gamma-ray (track 1); resistivity curves (track 2); porosity logs (neutron, density, sonic in track 3); calculated TOC (track 4). Fracturing is suggested by separation in the MSFL and LLD resistivity logs (shaded area) and higher sonic porosities compared to neutron and density porosity readings. The well was completed in the Sanish Sandstone for 167 BOPD. Green bar indicates DST interval.

1,968 Mcf/d. The well has a cumulative production of 359 MBO and 232 MMcf of gas.

Measured core porosity and permeability are also very low in the Bakken Shale, Sanish, and Three Forks reservoirs at the Antelope Field. According to the core analysis from the Duncan Rose #1 (section 33, T15N, R94W), the Lower Bakken Shale has porosities of 3.8% and permeabilities of 0.01 md. The Sanish has porosities ranging from 6% to 9% and permeabilities ranging from 0.08 to 0.33 md. The Upper Three Forks has porosities ranging from 8.3% to 10.6% and permeabilities ranging from 0.01 to 0.18 md. One foot of Three Forks 10609-10 reported a permeability of 6.88 md, but this is interpreted to be due to a horizontal fracture.

Reservoir pressure

The Bakken Formation is regionally overpressured because of hydrocarbon generation, and the overpressures cause hydraulic fractures in the Bakken by the generated liquids. Horizontal expulsion fractures have been reported in the Bakken shales in clay- and organic-rich intervals. The maturation process and oil generation also creates a bulk volume change and diminishment in the sound velocities in the Bakken shales that can be recognized utilizing sonic logs.

Reservoirs in the Bakken and Three Forks have pressure gradients that exceed 0.5 psi/ft. The highest overpressures are in Antelope and the Billings anticline areas where gradients were 0.7 psi/ft. Elm Coulee has a pressure gradient around 0.5 psi/ft. Parshall is reported to have a gradient of 0.7 psi/ft. The area west of the Nesson Anticline has pressure gradients of 0.5 to 0.6 psi/ft. Pressure gradients in Montana are generally in the 0.5+ psi/ft range. Research has described the role of overpressuring in the Bakken at Antelope and the creation of open tension fractures. The pressure gradient at Antelope is 0.73 psi/ft in the Bakken and the Upper Three Forks intervals. Normal pressures are found above and below the Bakken.

The abnormal pressures in the Bakken and the Three Forks suggest that the oil generated in the Bakken petroleum system has largely stayed in the Bakken petroleum system.

Fractures

Fracturing of source rocks has been frequently discussed as a mechanism that enhances primary migration and increases permeability of the source

rock. Fracturing observed in source rocks is commonly horizontal; however, oblique and perpendicular to bedding planes fractures also occur.

Low core permeabilities in the Lodgepole, Bakken, and Three Forks require a fracture network to be present for commercial production. Well testing in the Billings Nose area indicates that most wells have permeabilities ranging from 0.2 to 0.5 md. These permeabilities are much higher than those reported in core analyses data. Pressure buildup data indicate a homogeneous system with radial flow characteristics. Research has suggested that this implies the presence of numerous, low conductivity, microfractures in the pay intervals, with permeability variations a function of fracture density. A pervasive fracture system in the Billings Nose area was also indicated by low rates of production and pressure decline among the wells in the area. Rock cuttings show numerous microfractures, partially mineralized with horizontal, oblique, and vertical orientations. The Bakken has been described as the "best-interconnected reservoir" in the world.

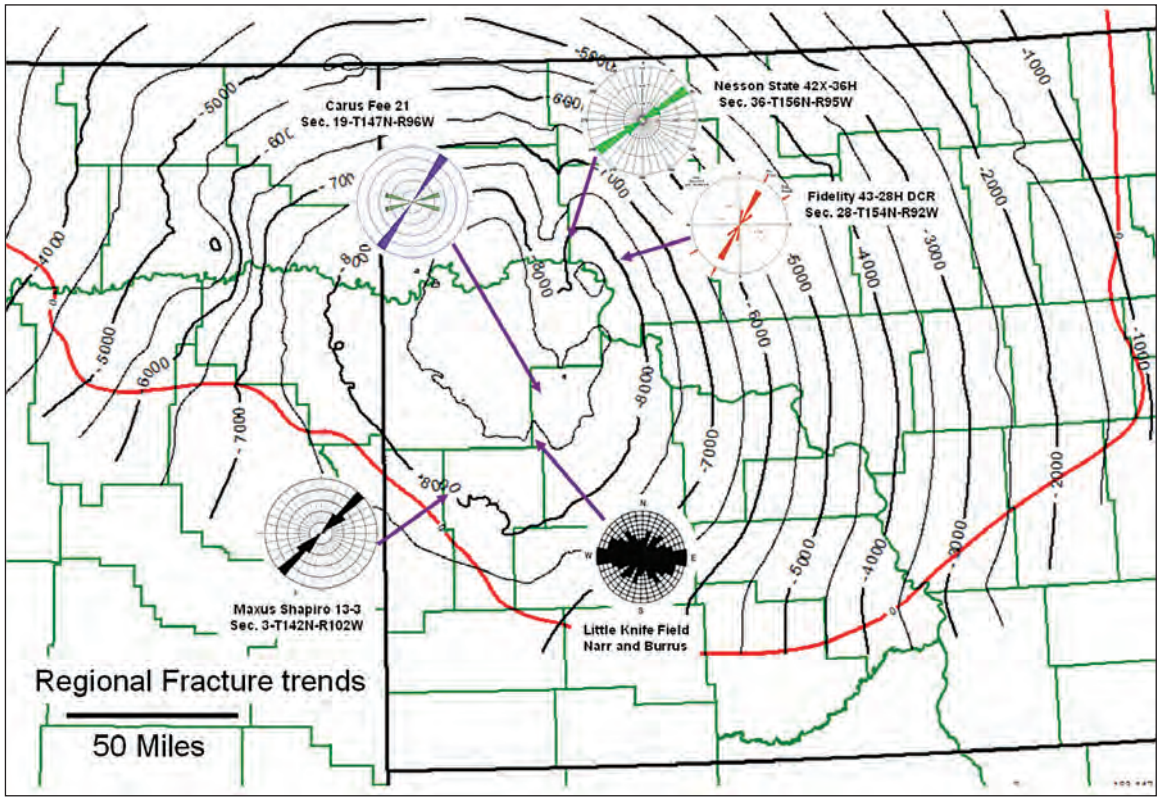
Fractures reported in the Bakken shales include the following types:

- Hair-like vertical fractures in more massive zones;
- Conchoidal fractures where there is an increase in silt;
- Open bedding plane fractures with residual oil staining;
- Closed vertical fractures cemented with calcite and pyrite; and
- Small-scale deformed fractures cemented with calcite or pyrite.

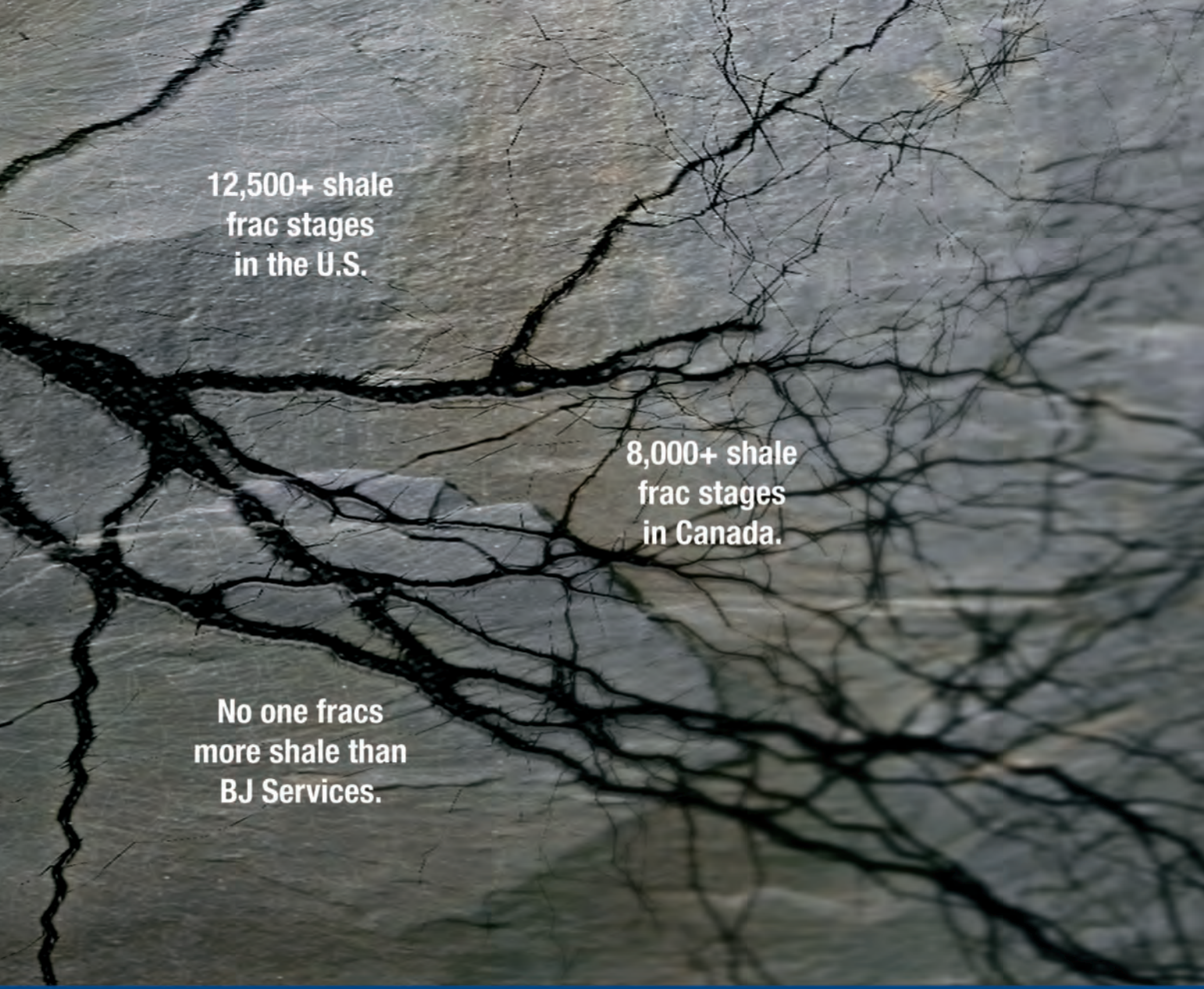
Pitman identified four types of fractures in the Middle Bakken:

- Sub-parallel to bedding fracture (associated with high residual oil saturations);
- V-shaped fractures occluded with pyrite and fine to coarse crystalline calcite (fluid-escape structures);
- Rare vertical extension fractures cemented with quartz and calcite; and
- Irregular and blocky or smooth and conchoidal fractures are common in the more siliceous shales.

The majority of fractures observed in the Middle Bakken were horizontal.



Rose diagrams show trends of regional open fractures in the Williston Basin. *(Source: Fracture orientation data from NDIC well files)*



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Considerable literature supports the existence of fractures and especially horizontal fractures in the Bakken and Three Forks. Structural geologists are generally opposed to horizontal fractures because of the maximum principal stress in most sedimentary basins is vertical, which is thought to preclude the possibility of horizontal fractures.

The Bakken Formation is regionally overpressured because of hydrocarbon generation and the overpressures cause hydraulic fractures in the Bakken by the generated liquids. The maturation process and oil generation also creates a bulk volume change and diminishment in the sound velocities in the Bakken shales that can be recognized using sonic logs.

Fractures enhance the reservoir quality of the tight Bakken reservoir and source rocks. Three types of open fractures are reported to occur in the Bakken: structural-related tectonic fractures; stress-related regional fractures; and expulsion fractures associated with overpressuring due to hydrocarbon generation.

The best production comes from hydrocarbon-generated related pervasive microfracturing within the Bakken, the Three Forks, and the Lodgepole combined with larger scale fracturing (i.e., structural-related or stress-related regional fractures).

Structural-related tectonic fractures

Several large fault-bounded anticlinal features — the Nesson and Cedar Creek anticlines — have had recurrent movement through geologic time. These large structural features are thought to exert controls on the orientation of fractures in various reservoirs.

The fractured reservoir in the Antelope Field has been described as the result of sharp folding of the Antelope structure (radius of curvature concept).

Stress-related regional fractures

Studies conducted on the regional stress field in the Williston Basin suggest a northeast to southwest or east to west orientation of the maximum horizontal stress. Vertical fractures paralleling the maximum horizontal stress are thought to be the open fracture direction. Natural fractures in the Mission Canyon in the Little Knife Field trend northeast to southwest to east to west, which is perpendicular to the trace of the Little Knife Anticline. Oriented cores in the Elkhorn Ranch and Roosevelt Field areas of the Billings Nose Bakken producing area suggest that the maximum horizontal stress is N45E. Multiwell interference testing in the Billings Nose area indicated restricted hydraulic communication exists between wells off the N45E trend. In other words, the open vertical fracture direction is N45E.

Well interference tests in Antelope Field in the area of the discovery well indicated communication between wells spaced on 160 acres. This interference was noted in wells that line up in a northeast to southwest trend. The Duncan Rose #1, located south of the discovery well, encountered almost virgin pressures in 1986. Thus, the biggest pressure interference and drawdown appears to happen in the northeast to southwest direction (suggesting regional fracture influence).

A summary of review of the interpreted open fracture orientation from various wells and field studies from the Williston Basin indicates the open fracture trend is northeast to southwest to east to west; most operators orient their wells to cross this fracture direction: north to south or northwest to southeast; and the fracture orientation remains fairly constant through various horizons. These regional fractures are the most important in terms of well production and performance.

Hydraulic fractures

New reservoir modeling of hydraulic fractures illustrates that planes of weakness (i.e., bedding planes or horizontal fractures) can alter the growth of hydraulic fractures. Interfacial slip is one of the mechanisms that can alter the growth of hydraulic fractures.

Artificial hydraulic fractures are thought to be parallel to greatest principal stress. In most basins, the greatest principal stress is overburden and vertical hydraulic fractures occur. Vertical fracturing, however, requires the section being fraced to be homogenous. Thinly interbedded lithologies (e.g., sandstones and shales) are inhomogeneous and failure of one rock at a lower pressure that the other probably results in horizontally fractured zones. Natural pore pressure tensional fractures in inhomogeneous zones (e.g., Middle Bakken) are also probably horizontal.

Fracture identification from wireline logs

Wireline logs can be used to detect naturally fractured reservoirs in the Bakken. Fractures are indicated in several ways:

- By separation on deep laterologs (DLL) and microspherically focused logs (MSFL);
- By the difference in sonic log porosity and neutron/density porosity;
- Borehole washout observed on caliper logs; and
- Changes in the density correction curve profile.

Vertical Bakken wells were generally drilled with either a salt-based mud system or an oil-based system. The ones drilled with the salt-based systems were generally logged with MSFLs and dual laterologs. Where fractures or matrix permeability is present, a wide separation in the curves is exhibited. The effect can occur when heavy salt-based mud is used in a hole to control the abnormal pressures in the Bakken and for minimizing salt dissolution in several of the shallow salt horizons in the Williston Basin (e.g., Charles salts). This is an indication of invasion profile and probable formation damage. The separation in the curves results from invasion of the salt-based mud into the formation. Because the Lodgepole, the Bakken, and the Three Forks have low permeabilities and porosities, separation can be attributed to the presence of natural fractures.

The MSFL tool is a shallow depth of investigation logging device. The device illustrates the presence of fractures because of the salt-mud invasion into the near well bore. The DLL device is a deep resistivity reading tool and measures the true resistivity of the formation. It measures the resistivity of the hydrocarbon-saturated intervals. The MSFL/DLL separation is useful to identify areas of natural fracturing or matrix development.

Formation damage caused by invasion limits shows in the Bakken and also results in poor recoveries on DSTs of the Bakken interval.

Analyses from the Rose #1 well (section 33, T152N, R94W) show significant invasion profiles in both the Scallion member of the Lodgepole, and the Upper Bakken and Lower Bakken shales. Modest invasion also occurs in the Middle Bakken interval. Wells in close proximity to the Duncan Rose #1 also show significant invasion profiles in the Upper Three Forks and the Middle Bakken. Thus, the Lower Lodgepole and the Bakken intervals are interpreted to be fractured in the Duncan Rose #1.

Caliper logs generally show borehole enlargement where fracturing is present. The Bakken shales in the Rose well illustrate borehole enlargement in the same areas where the filtrate invasion has taken place.

The density correction curve ($\Delta\rho$) also shows the largest correction effect where the inferred microfractures are located. The profile shows a serrated pattern through the Bakken shales in the Antelope wells.

High sonic log porosity compared to the density and neutron porosities also suggest the presence of microfractures. The high transit times in the shales may be due to a microfracture network saturated with oil. The fractures and the oil both contribute to low sound-velocity (high transit times).

In summary, fractures can be remotely detected with four criteria from the wire line logs: MSFL/DLL separation; borehole rugosity or enlargement on caliper logs; large correction on the $\Delta\rho$ log; and high sonic log porosity compared to neutron and density logs. The example shown in this overview from the Duncan Rose #1 suggests that both the Upper Bakken and the Lower Bakken shales are intensely fractured and the Middle Bakken is moderately fractured.

Summary

The Bakken and the Three Forks are an important tight oil resource play. The production in the Williston Basin is increasing dramatically because of the excellent results in recent drilling. The amount of recoverable oil has recently been estimated by the NDIC to be 4 Bbbl (1.9 Bbbl from the Three Forks and 2.1 Bbbl from the Bakken). New technology and enhanced recoveries may add to the number in the future. The cumulative production from the Bakken/Three Forks is currently around 244 MMbbl of oil. Thus, the play is in its early stages. Production from both the Three Forks and the Bakken is excellent. Both fracture and matrix permeability is important in the play.

Fracturing in the Bakken petroleum system occurs from a variety of causes: pore pressure

related; regional stress field; local structures (including salt dissolution features); and recurrent movement on basement fault systems. The regional stress field appears to play a significant role in how operators are orienting their laterals and overall production.

Many of the reservoirs in the Bakken petroleum system have low permeability. Productive areas, or sweet spots, are localized areas of improved reservoir permeability through natural fracturing or development of matrix permeability, or combination of both. Reservoir facies with matrix permeability are key to areas like Parshall and Elm Coulee.

References available.

Expulsion fractures associated with overpressuring

Expulsion fractures associated with overpressuring have been the subject of much research. Microfracturing due to overpressuring of enclosed pore fluids has been reviewed by Tissot and Welte. The model proposed is that a large increase in pore pressure may be sufficient to overcome the capillary pressure or even exceed the mechanical strength of the rock and induce microcracking. These types of microfractures are restricted to deeply buried, compacted, low-permeability rocks. With thermal maturity, organic matter generates liquid or gaseous low molecular-weight compounds. The mechanical strength of a rock is exceeded and fracturing occurs if the internal fluid pressure in a rock or in local pressure centers inside the pores is greater than a factor of 1.42 to 2.4 over the hydrostatic pressure in immediate surroundings. Pressures that exceed normal hydrostatic and even lithostatic pressure are possible whenever massive generation of gas and oil from kerogen takes place.

Horizontal expulsion fractures have been reported in the Bakken shales in clay- and organic-rich intervals. Carlisle, Pitman, and Price and Stolper have discussed hydrocarbon generation resulting in super-lithostatic pressures that could create the horizontal fractures. Price also discusses the model using early CO2 generation and light hydrocarbons also creating high overpressures.

Price also addresses the question of horizontal fractures. As he has pointed out, most geologists consider them to be impossible and think they originate from desiccation or stress relief during the coring operation. Price argues for the super-lithostatic fracturing related to hydrocarbon generation. The following are some observations from the Price model. The fractures created by hydrocarbon overpressures are dominantly horizontal and are rarely mineralized. He also said that early CO2-driven expulsion of indigenous bitumen occurs. Copious amounts of CO2 are generated at immature ranks from highly organic-rich source beds. Water present in the shales chemically reacts with kerogen, with hydrogen from the water hydrogenating the kerogen and oxygen from the water given off as CO2. C2 to C4 gases also are generated in small amounts. The sum total of these reactions is a volume expansive reaction (products taking up greater volume that the reactants).

Vernick has proposed a model involving a rotation of the stress field associated with the thinly bedded Bakken interval; deviatoric stress reduction; and strong mechanical strength anisotropy of kerogen-rich shales caused by bedding-parallel alignment of kerogen microlayers and clay (illite) platelets to get away from the vertical principal stress issue. Vernick also has supplied considerably geophysical evidence for the existence of horizontal fractures. Laboratory measurements of ultrasonic velocity and anisotropy in Bakken shales suggest extensive, bedding-parallel microcracks exist insitu. He noted that the fracture toughness of bedding-parallel cracks has been shown to be 30% lower than that of bedding-perpendicular ones in both kerogen rich and poor shales. Bedding parallel microcracks were noted by Vernick in many Bakken cores. Vernik cites SEM work that illustrates overlapping illite platelets as being the sites for initial flaws. Penny-shaped microcracks develop between two dissimilar minerals. Microcracks originate in kerogen-illite interfaces because of extreme low-fracture toughness of organic material.

Experimental data on horizontal fractures

In addition to the Bakken literature, there is other literature on organic rich shales that describes horizontal fractures. Lempp artificially generated horizontal microfractures in the laboratory using triaxial compression tests on Toarcian source rocks from south Germany. The paper is very significant in that it reproduces in the laboratory what is observed in many cores.

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Bakken Bolsters Bottom Line

Operators expand potential of Bakken-sourced pay.

By Don Lyle
Contributing Editor

The Bakken Formation in North Dakota, Montana, Saskatchewan, Manitoba, and even into British Columbia is a bonanza. No one doubts it, and no one has a firm grip on the full potential.

Meridian Resources, a subsidiary of Burlington Northern Railroad at the time, drilled successful horizontal wells to the Bakken in North Dakota in the late 1980s, but that play faded.

Estimates of the resources in place climbed steadily into the billions of barrels of oil over the years, but a lack of effective recovery techniques stifled exploration.

Then, in 2000, operators at Elm Coulee Field in Montana brought in huge quantities of oil – enough oil that it prompted the US Geological Survey (USGS) and North Dakota officials to take a closer look at the potential.

USGS estimates noted oil in place as high as 503 Bbbl over the 25,000 sq miles covered by the Bakken in the Williston Basin. In its now-famous 2008 report, it calculated the fully risked undiscovered resources at 3.65 Bbbl of oil, 1.85 Tcf of gas, and 148 MMbbl of natural gas liquids in the Bakken and the Lower Lodgepole immediately above it.

Although many companies already had entered the play, the boom officially was on; not only on, but expanding, as operators determined the Three Forks/Sanish below the Bakken was a separate formation with nearly the recoverable resource as the Bakken.

Some two-thirds of the Bakken land was in North Dakota, and that still is the focus of the play.

In an article in the *Bismarck Tribune* (North Dakota), Lynn Helms, director of the North Dakota Oil and Gas division, estimated 2 Bboe of recoverable resource in North Dakota from the Three Forks/Sanish.

Harold Hamm, chairman and chief executive officer of Continental Resources Inc., one of the largest operators and one of the pioneers in the play, estimated recoverable resources in the Bakken and Three Forks/Sanish complex at 8 Bboe.

By 2010, the Bakken had become the biggest onshore oil play in both the US and Canada, and it still was growing as operators extended the play in isolated pockets as far as western Montana in the US and into northeastern British Columbia in Canada.

US Key Players

Abraxas Petroleum Corp.

Abraxas Petroleum Corp. held some 60,000 gross, 30,000 net, acres of land with potential for Bakken and Three Forks production. It's not worried about expiring leases because nearly all of the land is held by production from other zones.

In a January 2010 presentation, the company said it had three operated lease blocks close to commercial Bakken/Three Forks production.

Most of the company's properties producing from other formations are in McKenzie, Williams, Dunn, Divide, and Burke counties in North Dakota.

It also had a 10% interest in a well being completed in the Bakken/Three Forks by BTA Oil Producers LLC. BTA drilled that well to 16,200 ft, including a 7,000-ft lateral. That measurement included a sidetrack when the drillpipe stuck in the original lateral leg.

The companies planned a 20-stage fracture treatment to complete the well.

According to the company it has 90 drilling locations

on 1,280-acre spacing, but that didn't include locations in the Lewis & Clark area with Three Forks potential in west-central North Dakota.

Overall, Abraxas locations that produce from other zones range from the Nesson Anticline, property in and around top-ranked Parshall Field in North Dakota, and along the Cedar Creek Arch in Montana and North Dakota.

For 2010, Abraxas allocated a portion of its US $30 million capital program to investigate the Bakken/Three Forks with an eye to possible expansion in the formations. Part of that budget was committed to fund the company's first operated well to test the Bakken/Three Forks combination in 2Q 2010.

Until July of 2009, Abraxas had monitored activity by other operators around its leases and participated in wells planned by other operators. Abraxas kept a working interest in wells on its property. Those operations provided insight into the most efficient drilling and completion techniques.

In one case, an experienced operator in the area completed a horizontal Three Forks well in McKenzie County with a multistage fracture treatment for an initial production rate of more than 700 b/d of oil. At the time of the report, the well continued to produce some 300 b/d of oil. Abraxas kept a small working interest in the well.

"We are pleased to have the opportunity to sit back and learn more about the Bakken/Three Forks resource plays, where drilling and completion technology advances are continually being made, before we invest significant dollars in drilling and operating our own wells with a much larger working interest. With improving economics due to industry innovations, which are driving down costs coupled with increased performance and firmer oil prices, these Rocky Mountain resource plays may prove to be a significant growth driver for Abraxas for years to come," said Bob Watson, president and chief executive officer.

AltaCanada Energy Corp.

AltaCanada Energy Corp. has a strong land position in Montana and Saskatchewan, including properties with Bakken Shale potential, but the company has yet to drill a Bakken well.

AltaCanada concentrated on natural gas activity, and, when prices collapsed in mid-2008, the company had to restrict its drilling activities. Much of its production came from leases on the Fort Belknap Indian Reservation that produced natural gas. In Montana, the company operates as Montana Land & Exploration Inc.

In its 3Q 2009 report, the company said it held 400,000 gross, 270,000 net, acres in the play and was raising capital to look for light oil on its land. That land in Montana was on trend with the Shaunavon oil play in Canada.

At that time, the company planned no immediate drilling for gas, but, with a recapitalization plan in place, it planned three Jurassic Shaunavon wells and one 50%-owned Bakken exploratory well.

In December 2009, the company placed two million warrants for common stock and US $3.12 million (Cdn $3.25 million) in debentures.

In the company's 2008 annual report, it said it had identified considerable Bakken and Jurassic oil potential on its Montana property.

"The Bakken exploration potential is less controlled [than the Jurassic], as only 15 Bakken tests have been undertaken on this sparsely drilled portion of the basin; however, the Bakken potential remains substantial," it said.

The nearest established Bakken production is more than 100 miles from the company properties, but it planned a Bakken test to 4,700 ft to evaluate the potential.

American Oil & Gas Inc.

American Oil & Gas Inc. showed its regard for the Bakken play in North Dakota as it sold off a considerable portion of its Powder River Basin properties in eastern Wyoming to raise money for further Bakken/Three Forks operations.

In February 2010, it entered into a letter of intent to sell its ownership in non-producing and producing wells and undeveloped acreage in the Powder River Basin for approximately US $44 million.

"Closing of this sale should allow us to focus our financial and human resources primarily on accelerating the development of the Bakken and Three Forks potential within our Goliath project area," said Pat O'Brien, chief executive officer. That potential included locations for 100 to more than 350 net wells.

The company's Goliath project in Williams County, N.D. – immediately west of the Nesson Anticline –

included 102,000 gross, 76,000 net, acres, and American held a 95% working interest in that net acreage. The company also had Bakken/Three Forks properties in Dunn County, N.D., with Sundance Energy Ltd. of Australia as its 5% partner.

It drilled its first Bakken wells in 2006 using state-of-the-art techniques at the time – trilateral wells with single-stage frac jobs with Evertson Energy Partners LLC as a partner. It later bought Evertson's share of the properties.

In a 1Q 2010 presentation, American said the industry has experienced dramatic results from new completion techniques.

Its initial wells in the Bakken were trilateral wells with single frac stages with some initial production rates in the double digits. A competitor's well was completed for 70 b/d of oil. A 2009 completion with a single long lateral and a multistage completion tested for 727 b/d of oil.

That is not an isolated example. The company said a Brigham Exploration Co. well with a 30-stage fracture treatment showed an initial potential of 3,807 b/d of oil and another, with a 32-stage frac, tested for 3,394 b/d of oil.

To further its position in the Bakken/Three Forks play, American signed a joint venture agreement in December 2009 with Halliburton Energy Services. Under that agreement, Halliburton will pay American up to $1.1 million and agreed to pay all of the drilling and completion costs of the Tong Trust 1-20H well to earn 25% of American's interest in 7,500 acres in the eastern portion of the Goliath block, which consisted of about 30,000 acres. American retained 30% of the Tong Trust well and 75% of the eastern block.

The companies spud the Tong Trust well in December 2009 and planned a 9,000-ft lateral with up to a 24-stage fracture treatment.

In late February 2010, American said drilling had started on its Ron Viall 1-25H in Williams County, and casing had been set in the curved section of the horizontal well with plans for a 9,000-ft lateral leg.

At the same time, it said the Tong Trust 1-20H well was scheduled for completion in early March 2010 with plans for a 26-stage fracture treatment.

Also on the western edge of the company's Goliath area, American held a 6% working interest in the outside-operated Heidi 1-4H well. That well targeted the Three Forks Formation immediately below the Lower Bakken.

Brigham Exploration Co.

Brigham Exploration Co. carved its niche among the top operators in the Bakken/Three Forks play in North Dakota and Montana using focused land acquisitions and the application of advanced technology.

That strategy directed the company to some of the best wells in the best operating areas in the still-evolving area.

According to a February 2010 presentation, it was a pioneer in the use of long, single-lateral horizontal wells with 30 or more fracture stages separated by swell packers, the use of perf-and-plug techniques to maximize fracture wings and the use of high-strength ceramic proppants to keep those wings open to production flows.

Brigham documented the results. An early 2009 well in the Rough Rider area showed an initial production of 1,433 boe/d. The company's four latest wells averaged 3,314 boe/d.

In spite of laying down its operated rigs in the first two quarters of 2009, Brigham managed to de-risk its 105,000-acre Rough Rider area to add 245 net Bakken locations to its inventory, based on 1,280-acre spacing and three wells per spacing unit.

It confirmed the presence of Three Forks formation across most of its Ross area and completed the Strobeck well in southeast Ross and the Liffrig well in northwestern Ross.

The company re-activated one operated drilling rig in 3Q 2009 and another in 4Q 2009. It planned to work four rigs in the play during 2010.

Those rigs are backed with some US $199 million in capital expenditures for exploration and development to drill a net 25.7 wells. That compared with four wells each in the Rough Rider and Ross/Parshall areas during 2009.

The rationale for the search for oil in the Bakken and Three Forks shows up in basic economics. Oil commands a price advantage over natural gas, and with the abundance of low-priced gas from shales, that advantage is likely to last for some time, according to Brigham.

Based on a drilling finding cost of $13/boe in the Bakken/Three Forks and a 12-month New York Mercantile Exchange (NYMEX) strip price of $82/bbl, the differential is $69/boe for oil. While the drilling finding cost on the four most popular gas shale plays ranges from $7/boe to $10/boe, the 12-month NYMEX strip is equal to $32/boe, a differential of $24.

Those economics drive the company's plan to raise average production from 2,867 boe/d in 2009 to 4,930 boe/d for all of 2010.

In the presentation, Jeff Larson, executive vice president of exploration, said the company held 278,400 net acres of land in the Williston Basin with room for 219 initial wells and 1,055 development wells. That doesn't count another 9,100 acres in an additional extension area.

The company's Ross/Parshall and extension areas – 99,000 net acres – have given Brigham average initial recoveries of 2,217 boe/d. The Rough Rider area – 105,000 net acres – yields an average 2,428 boe/d initial recovery from Bakken with Three Forks potential throughout the area.

The 84,000 net acres in Roosevelt County offers production from Bakken, Three Forks, Red River, and other zones.

In mid-April 2010, Brigham added another 10,000 net acres to its Rough Rider properties to raise acreage in that play to 115,000 net aces and its core position in North Dakota to 157,000 net acres.

The company continued to register impressive results. Brigham has completed 16 consecutive long-lateral, high initial-potential operated wells with average initial 24-hour test rates averaging 2,417 boe/d.

Brigham has logged some impressive recoveries, and its wells show the early production dropoff of Bakken wells.

Its top well was the State 36-1 #1H, competed with 30 frac stages for 3,807 boe/d initial potential. Its average for the first week of production was 2,497 boe/d, and for the first 30 days, 1,516 boe/d.

The second-place Jackson 35-34 #1H initially tested for 3,540 boe/d after a 30-stage frac job, and tapered off to an average 1,616 boe/d for the first seven days and 907 boe/d for the first 30 days.

The Williston 25036 #1H, with 32 frac stages, showed an initial recovery rate of 3,494 boe/d, eased to 2,342 boe/d over the first seven days online, and to 1,505 boe/d for the first 30 days of operation.

Bud Brigham, chairman, president, and chief executive officer, said, "Our staff continues to enhance both drilling and completion efficiencies and techniques, delivering exceptional operational results. For example, our most recent well, the Jerome Anderson 15-10 #1H, took only 18 days from spud to reach a total depth of

Brigham holds a substantial inventory of Bakken and Three Forks drilling locations in its five major project areas in North Dakota and Montana. *(Table courtesy of Brigham Exploration Co.)*

Brigham Potential Net Locations

Project area	Producting Formation	Brigham Net Acres	Drilling Unit Size	Initial Wells	Development Wells	Total Wells
Parshall/Austin/ Sanish	Bakken	5400	640	8	17	25
	Three Forks	2700	640		12	12
Ross	Bakken	36,400	1280	28	57	85
	Three Forks	36,400	1280		85	85
Rough Rider	Bakken	104,700	1280	81	164	245
	Three Forks	104,700	1280		245	245
Core Development Acreage		**146,500**		**117**	**409**	**490**
Future Projects						
Montana	Bakken	83,600	1280	65	130	195
	Three Forks	83,600	1280		195	195
Mercer	Bakken	32,400	1280	25	50	75
	Three Forks	32,400	1280		75	75
Northeast Extension	Bakken	15,900	1280	12	25	37
Future Potential Development		**131,900**		**102**	**475**	**577**
Total		**278,400**		**219**	**1055**	**1274**

Excludes 9,100 acres in additional extension area.

19,350 ft, which is an improvement from our typical well drilling days of 22 to 26 days."

Most of the company's completions have been in the Bakken Formation, but the Three Forks performs as well. In July 2009, Brigham said its Strobeck 27-34 #1H in the Ross area in Mountrail County, N.D., tested for 2,021 boe/d from the Three Forks. That broke down to 1,788 b/d of oil and 1.4 MMcf/d of gas.

The company said that well appeared to be the second-best Three Forks producer in the play after XTO Energy Inc.'s Boucher 41X-21, which tested for 2,571 boe/d.

The company issued 14 million shares at $18/share in April 2010, with plans to accelerate its Bakken drilling program, according to Jefferies & Company, Inc. The company planned to raise its rig count to eight by May 2011 from four rigs in action in early 2010.

Jefferies analysts said the accelerated program could convert nearly 500 Bcf of gas equivalent in probable reserves to proved by the end of 2011. The company's previous estimate was the conversion of approximately 300 Bcf of gas equivalent. They estimated the program would increase probable reserve locations to 615 from a previous estimate of 400.

The analysts also noted that Hess Corp. has proposed downspacing to six wells per 2,560-acre unit, or 427-acre spacing. That proposal joined forecasts of downspacing in some of the less-prolific areas of the play. Brigham and Continental Resources Inc. were pioneers in suggesting downspacing to as little as 320 acres.

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BTA Oil Producers LLC of Midland, Texas, is a long-time producer in the Williston Basin, working zones from the shallow Eagle to the deep Red River, and the Bakken holds a place in that list of accomplishments.

Although the private company doesn't report its activities publicly, some records are available from sources outside the company.

At the late February 2010 meeting of the Montana Department of Natural Resources, the company applied for temporary spacing units in both Roosevelt and Sheridan counties for horizontal Bakken wells.

According to IHS Inc., the company drilled the 31-8 9210 JV-P to Bakken in Roosevelt Field in late 2009 and early 2010, but it plugged and abandoned the well.

It tested a Bakken vertical development well, the 1313 JV-P Olson – in Stoneview Field in Divide County, N.D. – for 13 b/d of oil and 26 Mcf/d of gas in 2007.

The company also has drilled to the Madison, Stonewall, and Winnipegosis formations as one of the more active operators in the basin. In 2008, BTA was the 13th most prolific operator in North Dakota, with 746,427 bbl of oil and 2.3 Bcf of gas from 175 wells, according to Bakkenstocks.com.

In a January 2010 presentation, Abraxas Petroleum Corp. said it had a 10% working interest in a Bakken/Three Forks well operated by BTA.

CAVU Resources Inc.

The CAVU in CAVU Resources Inc. stands for an old World War II term used by aviators. It stood for "ceiling and visibility unlimited," and the company counts some Bakken properties among its unlimited opportunities.

In December 2009, it had signed an option to acquire acreage in northeastern Montana in an area prospective for Bakken oil. It planned to test the area with an initial well, and, if that well was successful, CAVU said it would acquire additional acreage north and east of Elm Coulee Field in Richland County, Mont.

"We are acquiring this acreage for a number of reasons, not the least of which is that this (experienced) geologist believes there is between 600,000 and 750,000 bbl of recoverable oil on each well drilled on a 640-acre spacing in the Middle Bakken member," said William Robinson, president of CAVU Resources, Inc. "Another key reason is that the acreage is also strategically located in the middle of acreage positions held by four other large companies – a well recently drilled by this group showed good results," he added.

Cirque Resources LP

Cirque Resources LP is a fairly new company, but its management is tuned in to geology in the Rocky Mountains.

Peter Dea, chief executive officer and president, is well known in the Rocky Mountain oilpatch from his experience and success as an officer of two other oil companies. He was chairman and chief executive officer of Barrett Resources Corp. until it was purchased by The Williams Companies Inc., and president and chief executive officer of Western Gas Resources Inc. until Anadarko Petroleum Corp. acquired that company.

Dea proved he was willing to take risks calculated to succeed in private life, too, with mountain climbing experience in the US, Europe, Asia, and Africa.

According to the *Bakkenshale.com* Web site, on Feb. 10, 2010, Cirque had the Nabors 165 rig working on the Gunnison State 44-36H well in section 36, 161n-91w in North Dakota.

A Jan. 13, 2010, report from the same source said Cirque had 11 wells on North Dakota's tight hole list. Those wells were the Nut Brown 10-16H, the Roustabout Stout 1-3H, the Harpoon Harvest 14-4H, the Honkers 9-16H, the Alaskan Amber 11-3H, the Red Lady 36-4H, the True Blonde 16-15H, the Mad Hatter 16-4H, the Feast of Fools 12-16H, the Fire Rock 29-16H, and the Gunnison State 44-36H.

CNX Gas Corp.

CNX Gas Corp., a major gas producer in the East, with holdings in coalbed methane and the Marcellus, Huron, and Chattanooga gas shales of Appalachia and the New Albany Shale in the Illinois Basin, took advantage of circumstances to gain a position in the Bakken Shale in North Dakota.

"For the first time in our history, we contributed acreage and invested working interests in the Bakken Shale and Trenton Black River plays with large and well-established operator partners," said Nicholas J. Deluliis, president and chief executive officer, in his 2007 report to shareholders.

In the company's projection of plans for 2008, it said it would have a non-operated interest in several Bakken Shale wells in North Dakota, drilled and

prospective, with Marathon Oil Corp.

In its 1Q 2008 conference call, Deluliis said only that the Bakken program with Marathon had been positive.

Neither company identified locations for the planned wells, the properties in the area of mutual interest, or the amount of money that would go into the program.

CNX ordinarily doesn't acquire property prospective for oil, but it did complete a land swap with Peabody Coal in June 2007 that gave it 11,000 acres of properties in the Rocky Mountain area, in addition to properties in the Powder River Basin. More than 99% of the company's 1.9 Tcf in proved reserves are in natural gas.

Marathon is one of the largest acreage holders in the Williston Basin and the Bakken Shale play. At the time of the arrangement with CNX, it held more than 320,000 acres with Bakken potential in North Dakota, and planned more than 300 wells to produce 20,000 boe/d by the end of 2012.

Concho Resources Inc.

Concho Resources Inc. claims the Permian Basin in West Texas and southwestern New Mexico as its core operating area, and the only operations it has outside that core are in the Bakken/Three Forks play in North Dakota.

It was the sixth largest oil producer in the Permian Basin and the most active company in terms of permitting and current rigs running in 2009.

In North Dakota, it held 2.64 MMboe in proved reserves in the Bakken/Three Forks play; some 77.6% of that in oil and 35.2% proved developed.

The company had 146 gross drilling locations on 42,210 gross, 11,193 net, acres of land and its properties gave up 511 boe/d in production at the end of 2009.

Nearly all of its activity is focused with Newfield Exploration Co. in a 50-50 joint venture on 8,000 net acres in the Westburg area of McKenzie County, N.D. Its remaining Williston Basin properties are in Mountrail County, N.D.

According to Concho, initial production rates from the four most recent Westburg wells, with Newfield as the operator, have ranged from 600 to 1,400 boe/d.

The company participated in 25 Westburg area wells in 2009 and allocated US $30 million to its Bakken/Three

Forks play for 2010.

ConocoPhillips Co.

ConocoPhillips Co. has plenty of projects around the world where it makes exploration and production investments. With all those choices, it selected the Bakken play in Montana and North Dakota as one of its focus areas.

According to its 2009 investor presentation, ConocoPhillips was the largest onshore oil and gas producer in North America with 1.1 MMboe/d. It held 29.1 million net acres of developed and undeveloped land and was the largest producer in the San Juan Basin of New Mexico and Colorado with 1.1 Bcf/d of gas equivalent.

It was one of the largest acreage holders in the Bakken play, with more than 400,000 net acres at its disposal. Among its North American resource plays, it chose to concentrate its funds on the Bakken in North Dakota, the Barnett and Eagle Ford gas shales in Texas, and the Montney tight sand-shale play in Canada.

The company planned to spend US $4.1 billion on all plays in North America in 2010, with an emphasis on the highest-graded production basins and opportunities.

That included the Bakken play, the Barnett Shale, the Lobo trend in South Texas, and its San Juan and Permian basins properties.

ConocoPhillips entered the Bakken play through its acquisition of Burlington Resources Inc. in 2006. The major Williston Basin properties in that play were Burlington's Cedar Hills South unit, a horizontal line drive waterflood in the Red River Formation, and East Lookout Butte in Montana.

Burlington pioneered horizontal drilling in the US on its Bakken holdings in the 1990s at about the same time Amoco Production Co. was developing horizontal drilling in the Austin Chalk in Texas.

Current figures from ConocoPhillips weren't publicly available, but in 2008, the company produced 40,000 b/d of oil, 19 MMcf/d of gas, and 1,000 b/d of NGLs from the Williston Basin. Those numbers made the Williston the company's largest Lower 48 oil producing area, with the 24,000 b/d from the Permian Basin in a distant second place.

According to Continental Resources Inc., it entered an agreement with ConocoPhillips in June 2006 to form an area of mutual interest in Dunn, McKenzie, Mountrail, and Williams counties in North Dakota to test production potential of the Bakken.

The Continental share of that area was 97,000 net acres. The agreement gave each of the companies the right to acquire a half interest in the exploration block acreage owned by the other company for $500/acre, a fair price at the time, but a bargain at 2010 prices in the play.

The companies each had three drilling rigs at work on the area of mutual interest in October 2007, and maintained that rig employment level at least through 2Q 2008, according to a Continental conference call.

During that time, both companies increased their use of multistage fracturing programs to increase productivity of their Bakken wells, compared with initial rates from their 2007 program.

In 1Q 2009, Continental said ConocoPhillips drilled three wells in the area of mutual interest. Seven-day initial tests on the wells showed 1,085 boe/d for the Iron Horse 31-2H (25% working interest for Continental), 927 boe/d for the Suline 31-12H (25% working interest for Continental), and 866 boe/d for the Waterton 34-32H (20% working interest for Continental).

Continental Resources Inc.

Continental Resources Inc. built itself into the top leaseholder in the Bakken play in Montana and North Dakota, and one of the top innovators in the play.

The Bakken was the company's primary growth generator in 2009, according to Continental's 4Q 2009 and full-year report. The growing North Dakota portion of the play provided 2.4 MMboe, double the level of the previous year.

During 4Q 2009, production from the Montana side of the play averaged 5,047 boe/d, down from 6,410 boe/d in the same period a year earlier.

On the North Dakota side of the border, production grew to 7,843 boe/d during the quarter, up from 4,401 boe/d during 4Q 2008, the company said.

Also during 4Q 2009, Continental set a company record for an operated well at the Hendrickson 1-36H in McKenzie County, N.D. That 95% working-interest well tested for 1,990 boe/d during a seven-day production test. Its best single-day production reached 2,105 boe with some 3,000 psi of flowing tubing pressure.

At the end of 2009, the company held 605,000 net

acres of leases in the play in Montana and North Dakota after adding another 70,000 acres during the year. By the end of February 2010, the land position had grown to 652,000 acres. It had 616 gross, 262 net, proved undeveloped drilling locations in North Dakota alone, and another 57 locations in Montana as it downspaced from 640-acre spacing to 320-acre spacing in developed areas. By the time the company made its May 2010 presentation at Hart's Developing Unconventional Oil conference, it held 773,053 net acres in the Bakken and said the play was mostly leased.

By May 2010, Continental had 500 unbooked North Dakota Middle Bakken locations with potential for an additional 210 MMboe in reserves, 300 unbooked North Dakota Three Forks locations with a potential 125 MMboe in reserves, and 200 unbooked Montana Bakken locations with 70 MMboe in potential reserves. Drilling on 320-acre spacing would increase reserves by 1.6 times those numbers.

Continental participated in 22 gross, 6.7 net, Bakken wells in N.D. in 4Q 2009, with average initial production rates of 1,070 boe/d in seven-day tests. That was a 96% higher test rate than the 546 boe/d rate during 4Q 2008.

It completed eight gross, 4.3 net, operated wells in North Dakota in the quarter, with six wells aimed at the Three Forks/Sanish zone below the Bakken. Those six wells averaged 1,242 boe/d in seven-day tests after 18-stage fracture treatments and some 100,000 lb of proppant per stage.

Strong results continued into 2010 as the company completed the Hawkinson 1-22H in Dunn County, N.D., for 1,667 boe/d in seven days. Its strongest single-day rate was 2,338 boe.

In all, Continental held 481,850 acres of Bakken leases in North Dakota at the end of 2009 (81% undeveloped) and it raised its land position to 488,500 acres by the end of February 2010.

On the Montana side of the Bakken play, Continental resumed drilling late in 2009. It completed the Rognas 2-22H on the northern edge of the Elm Coulee Field fairway for 841 boe/d, with a best-day rate of 1,014 boe, making it one of the company's best Montana Bakken wells.

Continental completed that well with technology brought in from the North Dakota operations, a 14-stage frac treatment, and more proppant.

It will keep at least one operated rig working in Richland County, Mont., during 2010, alternating between 320-acre infill wells and wells on undeveloped acreage. Some 60% of the company's 163,500 net acres in the Montana Bakken play are developed.

As Continental improved well production, it reduced costs by lowering drilling times, according to a January 2010 presentation. Wells took 45 days to drill in 2008. That number dropped to 28 days in the first half of 2009 and to 24 days in 3Q 2009.

In other technology improvements, Continental pioneered drilling and proved the potential of Three Forks/Sanish in 2008. Since half of the company's acreage has potential for development in both the Bakken and the Three Forks/Sanish, the company will concentrate on dual completions to raise reserve potential by more than 105 MMboe, the company said.

Continental asked the US Geological Survey to reassess Williston Basin resources based on the success of test wells in the Three Forks/Sanish zone.

In another technological development, Continental asked for, and the North Dakota Industrial Commission approved, an Eco-pad plan. Under that plan, Continental can drill four horizontal wells from a single Eco-pad and Continental doesn't have to observe the setback from section boundaries normally required.

Normally, standard drilling practices call for 40 acres of land for eight, five-acre pads. Continental would take only 14 acres to build two seven-acre Eco-pads to drill eight wells.

It started drilling the first of those pads late in 2009. Of the 24 operated rigs the company plans throughout its holdings in the US, six will drill Eco-pad developments.

Continental also has proposed tighter spacing for

Rate of Return

	Encore $4.5 million Single stage/re-frac	Industry $5.2 million Multistage
Estimated ultimate recovery	350,000 boe	350,000 boe
Aug. '09 NYMEX strip return	77%	47%
$60 oil/$6 gas	37%	23%
$50 oil/$5 gas	23%	14%

(Source: Encore Acquisition Co.)

Bakken wells in some areas of the play.

Credo Petroleum Corp.

Credo Petroleum Corp. participated in its first Bakken horizontal well early in 2010, and judging by the result, the company probably will become a big fan of the play.

The Petro-Hunt LLC 148-94-17D-08-1H well tested for 1,267 b/d of oil and 1.24 MMcf/d of gas, or the equivalent of 1,474 b/d of oil.

Credo held a 10% interest in the Petro-Hunt-operated well in Dunn County, N.D. Petro-Hunt tested the well on an 18/64- to 20/64-in. choke.

The company drilled the well on 1,280-acre spacing to a vertical depth of 11,150 ft, added a 9,200-ft horizontal lateral in the Middle Bakken Shale, and completed the well with a multistage fracture treatment. Petro-Hunt drilled through the Bakken in the vertical section of the test to log the deeper Three Forks/Sanish Formation, and the companies are evaluating that potential.

The well location was on the southwestern portion of Credo's property on the Fort Berthold Indian Reservation.

Petro-Hunt and Credo already have planned their second horizontal well on the property. They planned to spud the 147-94-3A-10-1H in April 2010 on another 1,280-acre spacing unit about four miles southeast of the first well. Credo holds an 18.75% working interest in that well.

The companies also have initiated title work for permitting and drilling additional wells in which Credo will hold interests.

Credo held 8,000 gross acres on the reservation with about 50 drillable Bakken spacing units. Credo held interests as high as 51%, depending on the size of the unit, and anticipated drilling additional development wells on the spacing units.

"We are extremely pleased with the test results of our first Bakken well. Initial production is right in line with our expectations. Our success on the 17D well certainly makes our acreage in the area prime for future development.

"In addition to the Bakken, other operators also are testing the Three Forks/Sanish Formation in the area of our acreage. I am encouraged by the Three Forks drilling results to date, which indicate that it is a separate commercial reservoir. We are carefully monitoring the activity because we recognize the positive impact that this formation can have on Credo's position in the Bakken," Marlis E. Smith Jr., chief executive officer, said.

Denbury Resources Inc.

Denbury Resources Inc. entered the Bakken play in North Dakota in a big way – by acquiring one of the largest landholders in the trend, Encore Acquisition Co., in March 2010.

Encore built a strong business by acquiring properties in and around the sweet spots of proven plays, and applying technology to increase the efficiency of production.

In an October 2009 presentation, the company said it produced 41,652 boe/d in the first half of the year, held 186 MMboe in reserves, and 80% of those reserves were proved developed.

It held more than 300,000 net acres in the Bakken play in North Dakota with an upside potential of 57 MMboe with only two wells per section, and it planned to spend US $64 million in 2009 to drill nine operated and 21 non-operated Bakken wells.

Along with a West Texas joint venture with Exxon Mobil Corp. and a Haynesville Shale program, the Williston Basin, with potential from the Bakken and the Cedar Creek Anticline, was one of its three key profit areas.

Its main Bakken fairway properties were in Williams, McKenzie, and Dunn counties, but it also had an extensional Bakken area to the northeast in northeast Mountrail and Burke and Ward counties.

In all its operations, Encore's position was strong enough that it attracted the attention of Denbury Resources, and the two agreed to a Denbury takeover of the company for $4.5 billion in November 2009. That acquisition took place in 1Q 2010.

Under that agreement, Encore shareholders would receive $15 in cash and $35 worth of Denbury common stock for each share of Encore stock.

Denbury said it could use the cash flow from the Bakken and other standing assets while it developed incremental production from CO_2 injection in certain of its key producing areas.

Encore was not afraid to depart from traditional completion practices. Many companies in the North Dakota Bakken play reported initial production rates of more than 3,000 boe/d using multistage fracture treatments in long single laterals.

Encore looked at 183 single-stage completions and 82 multistage completions and concluded multistage

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EOG's holdings showed the tremendous potential of the Bakken/Three Forks play. By April 2010, the company still had 17% of its core area wells remaining to be drilled. *(Courtesy of EOG Resources Inc.)*

Bakken/Three Forks Horizontal Well Potential

	Net Acres	% Acres Drillable	Well Spacing (Acres)	Net Remaining Locations	Resource/Well (boe)	Resource Potential (boe)
Bakken Core	100,000	100%	640	27	730,000	20 million
Bakken Lite	480,000	48%	320	724	290,000	210 million
Three Forks	580,000	25%	320	461	260,000	120 million
Bakken/Three Forks net proved developed reserves on December 31, 2009						**70 million**
Total net potential resources, including booked reserves						**420 million**

wells have higher initial production rates, but ultimate recoveries are similar. It found the cumulative production rate difference after one year was just 5 boe/d.

It also found that wells with a single-stage fracture treatment followed by a re-fracture treatment cost less than multistage frac wells without a re-frac.

The company looked at economics of a Bakken well with a seven-day initial potential of 378 boe/d, a well cost of $4.2 million for a single-stage frac, and $300,000 for a re-frac after 12 months online. It anticipated 280,000 boe in recovery from the single-stage frac well and another 70,000 boe from the re-frac for total reserves of 350,000 boe.

A multistage fractured well would cost $5.2 million for the same recovery, giving the single-stage/re-frac well a better rate of return.

Encore also expanded beyond the traditional Middle Bakken production zone as it drilled deeper to the Sanish Formation with its Charlson 11-16H well in Williams County in 2008. It was the first well in that formation, and it tested for 1,106 boe/d flowing through 7-in. casing. The company said the well also had favorable pay in the Bakken.

Its well was approximately four miles northwest of the best Sanish well drilled to that time, the USA 2D-3-1H. That well produced more than 560,000 boe in 19 months.

Encore owned 10,400 net acres in the Charlson area, with room to operate or participate in another 28 wells.

Dorchester Minerals LP

Information about Dorchester Minerals LP's operations in the Bakken is sketchy, but the company has a foothold in the play and has a history of rewarding investors.

In an April 2010 8-K Form filing, the company said it had agreed with five foundations, two partnerships, two individuals, and one trust to acquire outstanding partnership interests in Maecenas Minerals LLP.

Those interests, acquired for US $17.7 million, included mineral and overriding royalty interests in some 700,000 gross acres of properties in 17 states, but primarily in the Permian Basin of Texas and in North Dakota.

The North Dakota properties included leases in the Cedar Hills South unit and in properties in the Bakken Shale trend.

The company has taken an active interest in shale plays. In 2008, it leased 10,000 acres in the Fayetteville Shale play in Arkansas to operating companies and kept a 25% royalty interest. Under the agreement, Dorchester would be carried on all drilling, completion, and development costs on the land.

Earthstone Energy Inc.

The Bakken play in North Dakota and Montana may be the biggest oil play in the Lower 48, but that doesn't mean smaller companies are locked out of the action. Earthstone Energy Inc., formerly Basic Earth Science Systems Inc., is an active player.

During 2009, it participated in two Bakken wells in McKenzie County, N.D., with ConocoPhillips Co. as operator. Earthstone had a 1.13% working interest in the King's Canyon #21-27H and paid its US $64,000 share of drilling costs.

ConocoPhillips also drilled the Lassen #41-26H, with Earthstone holding a 0.114% working interest and a commitment to spend $8,000 on the well. "These two

wells are our fifth and sixth in the Bakken/Three Forks trend in North Dakota," said Ray Singleton, president.

By February 2010, ConocoPhillips had not reported commercial production.

Earthstone also held property at its Banks prospect 20 miles to the southeast of those wells, with Panther Energy Co. LLC as operator. In June 2009, Earthstone said Panther had completed the Roscoe 2H-8 horizontal well on the Banks prospect in early May. The well tested for 543 b/d of oil, 1.18 MMcf/d of gas, and 122 b/d of water from the Bakken. Earthstone had a 6.5% interest in Panther's share of that well.

Panther previously had drilled the Wil E. Coyote on the 13,000-gross-acre Banks prospect. Earthstone previously had signed over rights to its 20% share of the prospect to Panther, and Panther committed to carry Earthstone's costs on those two wells.

On future wells in that prospect, Earthstone would have to spend up to $360,000/well for working interests as high as 6.5%. In April 2010, Zenergy Inc. was drilling ahead at the Pederson #10-3H horizontal well on the Banks prospect.

The Denver company also held 4,200 gross, 2,100 net, acres of properties with potential for Bakken production in northern Sheridan County, Mont., in its South Flat Lake prospect.

In its 3Q 2009 fiscal report, released in February 2010, the company completed its first exploratory well in more than 10 years with the Crown #41-31 well. "Unfortunately, drilling operations did not yield commercially viable intervals, and the well was plugged," Singleton said.

In the same report, Earthstone said it entered a working interest agreement with Marathon Oil Corp. on the Paulson 44-9H well in Dunn County, N.D., which produced about 150 b/d of oil and 6.1 MMcf/d of gas from the Bakken. The company had a 0.9975% interest in that well.

That was the second well on a 1,280-acre spacing unit. The first well, the Paulson 14-9H, produced at about the same 150-b/d rate.

Earthstone also took an 8.40625% interest in the Mondak Federal #4-14H in North Dakota, but the operator, XTO Energy Inc., had not reported completion information in time for the 3Q 2009 report.

Enduring Resources LLC

Enduring Resources LLC, formed by managers of the former Westport Resources Corp. in 2004, aimed at long-life gas accumulations in mature onshore basins.

The company put together more than 185,000 net acres of leases in the Uinta Basin of Utah and East Texas where it continues to develop fields.

The concentration on natural gas, however, didn't stop the company from collecting a 100% interest in 8,122 net acres in the Bakken/Three Forks play in McKenzie, Mountrail, and Stark counties in North Dakota, according to a company offering of properties for sale through Meagher Energy Advisors Ltd.

The land lay within 16,964 gross acres, where the company held an 80% net revenue interest in its net acreage with leases expiring between 2012 and 2015. Most of the acreage was in McKenzie County.

Nearby operators included EOG Resources Inc., Whiting Petroleum Corp., Marathon Oil Corp., Conti-

Rolling North Dakota hills form a background for a Bakken Shale operation in the Williston Basin. *(Photo courtesy of Fidelity Oil & Gas)*

nental Resources Inc., Brigham Exploration Co., XTO Energy Inc., and Hess Corp., according to Meagher.

EOG Resources Inc.

Big companies like big plays, and EOG Resources Inc. is one of the largest independent oil and gas companies in the US. Entering 2010, it held reserves in the US, Canada, Trinidad, the UK, and China; and, in the US, its liquids growth drivers include the Bakken and Three Forks formations.

Like any large company with technical resources, EOG contributed to the play as well as taking production from it. It entered the play in 2003, with the first horizontal well in Elm Coulee Field in Montana. The company drilled the first Bakken well in Parshall Field – the Bakken sweet spot in North Dakota – in 2006, and introduced swell packer and staged fracturing technology to the Williston Basin later that year.

Through its activities and those of other leading operators, well results have become repeatable and predictable.

By the end of 2009, EOG became the largest oil producer in North Dakota, and, by April 2010, had drilled 242 gross horizontal Bakken/Three Forks wells to date – 163 in its core Bakken area, 68 in its Bakken Lite area, and 11 to the Three Forks zone. EOG planned 78 net wells during 2010, with 11 rigs drilling in 1Q 2010, and plans to add another full-time rig in 2Q 2010.

According to the company's April 2010 presentation, it has produced a cumulative 20 MMbbl of oil net to the company and current Bakken/Three Forks net production is 28,800 b/d of oil. EOG estimated its net production would average 32,500 boe/d for 2010, 36,500 boe/d for 2011, and 40,000 boe/d for 2012.

The cash cow in the Williston Basin is the company's North Dakota Bakken core area where EOG has some of the most productive wells in the play in Parshall Field.

The company also defined the size of the Bakken sweet spot and increased reserve potential in Parshall Field in Mountrail County, N.D.

Its confidence in the Bakken showed in its land acquisition approach. At the end of 2007, it was the second largest landholder in the play with some 320,000 net acres. By the end of 1Q 2010, that position had grown to 580,000 net acres, and the company said 330,000 were "effective" net acres – or low risk and economically prospective – in the Bakken core, Bakken Lite, and Three Forks areas. The core area in the Parshall Field, the company said, had the highest rate of return of any big oil play in North America.

The Bakken Lite area is the second prime piece of property in EOG's Williston Basin portfolio. That's an area around the core that added production and reserves to the company's stockpile. EOG also was able to use techniques and technology from the core area to enhance recoveries in the Lite segment.

The Bakken core and Bakken Lite plays are indicators of the company's conclusion that horizontal oil resource play returns are far more attractive than the rates of return for the deepwater Gulf of Mexico or Canadian oil sands.

The third component of the company's Williston Basin properties is the Three Forks Formation underlying the Lower Bakken zone. That formation extends through a large part of the Bakken trend in Montana and North Dakota, and EOG expected it to be productive under much of its acreage.

On the technical side, the company will continue to drill on 320- to 640-acre spacing and continue to test EOG-style completions on 1,280-acre spaced laterals in 2Q 2010. Current assumptions are that EOG will continue to drill wells in its core area on 640-acre spacing and wells in the Bakken Lite and Three Forks area on 320-acre spacing.

The company completed its wells with extensive fracture and post-fracture analysis, and uses between six and 30 staged fractures with multiple variations, depending on information fed back from the formation.

On the way to its present status in the play, EOG reduced decline rates and increased estimated ultimate recoveries as it distributed high-volume sand fracture treatments at equal spacing along laterals.

It also found that a 24-hour test was not an accurate indicator of well reserves, and six-month figures gave a more accurate picture.

Experience to date on company wells revealed an average Bakken core well required US $4.6 million to completion, offered an estimated ultimate recovery of 730,000 boe, and gave the company a direct after-tax rate of return higher than 200%. Bakken Lite and Three Forks wells cost $4.8 million to complete, but the Bakken Lite offered recoveries of 290,000 boe and a return of 37%, while Three Forks wells yielded 260,000 boe and a 27% return.

The Williston Basin continued to suffer from lack of

takeaway capacity to move its oil to markets. To mitigate that situation, EOG put a combined rail and pipeline system into operation near the end of 2009. The rail line transports more than 60,000 bbl of EOG oil per train from Stanley, N.D., to an unloading facility in Stroud, Okla., where it is shipped by pipeline to the Cushing, Okla., New York Mercantile Exchange pricing hub. It initially used two trains per week.

The company also put 76 miles of 12-in. pipeline into service from Stanley to an interconnect with the Alliance Pipeline where it initially moved 15 MMcf/d of liquids-rich gas to a processing plant near Chicago. The line offered a capacity of 100 MMcf/d of gas, and EOG planned to use 40 MMcf/d of gas of that capacity by the end of 2010 for its own gas and gas purchased from other operators.

Fidelity Exploration & Production Co.

Fidelity Exploration & Production Co. moved into the Bakken play in North Dakota with an aggressive drilling program.

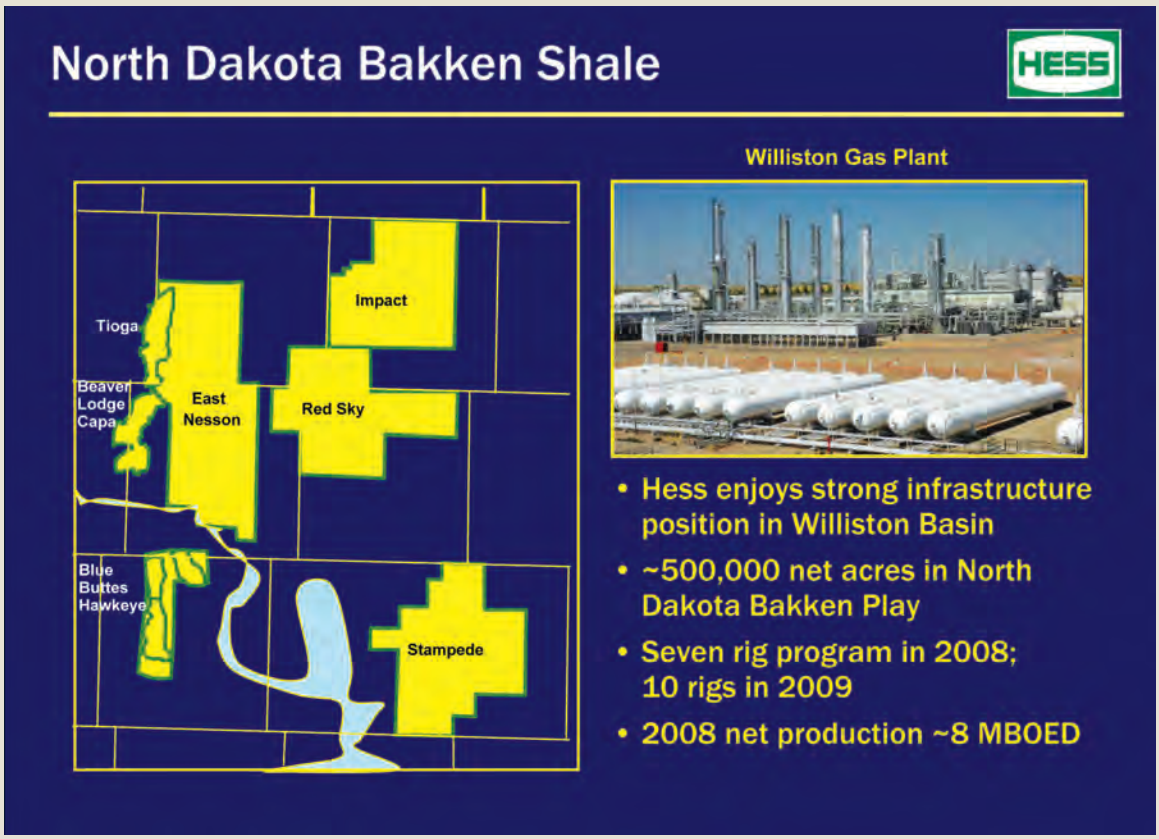
The company had operations around the country and produced 75 Bcf of gas equivalent, 25% oil, in 2009 from reserves of 654 Bcf of gas equivalent, 31% oil, from 7,575 gross, 3,379 net, wells.

The subsidiary of North Dakota's MDU Resources Group, Inc. utility drilled its first operated well in the Bakken in 2007, and built on that effort with further operated and non-operated wells, according to Fidelity president, Darwin Subart.

After successes in the Bakken zone, Fidelity drilled its first operated well into the Three Forks/Sanish Formation immediately below the Lower Bakken and sourced by the Lower Bakken. After a frac treatment, the Domaskin 11-29H well's average production over its first five days online in 2007 was 634 b/d of oil. Fidelity has a 58% working interest in the well. That well was in Mountrail County, N.D., home to that state's most prolific Bakken wells.

By mid-year 2008, Fidelity had spudded 14 wells aimed at the Middle Bakken in Mountrail and Burke counties, and had three drilling rigs working the area. It planned to participate in 50 to 60 wells in the Bakken, and about half of them were set up as operated wells.

According to an MDU January 2010 presentation, the company held 16,000 acres of Bakken properties, had one



Some 500,000 acres of Hess Bakken properties lie north and south of Lake Sakakawea in North Dakota. *(Map courtesy of Hess Corp.)*

rig working the play, and had 2,500 b/d of net production.

It planned US $45 million in capital expenditures in the play at a gross well cost of $5 million to $6 million for wells from 10,000 to 10,5000 ft true vertical depth with horizontal legs from 6,000 to 10,000 ft. In March 2010, the company added another 40,000 net acres to its North Dakota holdings with the Three Forks as the primary objective. That purchase increased the company's land position to 56,000 net acres.

FieldPoint Petroleum Corp.

FieldPoint Petroleum Corp. – with properties in Louisiana, Texas, New Mexico, Oklahoma, and Wyoming – expanded its search for hydrocarbons into North Dakota and properties prospective for Bakken Shale production.

The company acquired oil and gas properties after identifying promising prospects through outside consultants. When it acquires a property, it either drills through an independent contractor or attempts to sell the properties to a third party.

In January 2010, the company said it acquired a 440- to 800-gross-acre lease in Renville County, N.D. Although that county is outside the traditional Bakken area, the company said, it borders on the Bakken Shale oil play.

FieldPoint paid an average US $155 an acre on the leases, with an average royalty of 16% to 20%.

"We are looking to the future, and this unconventional shale oil is a grassroots opportunity. If we are able to acquire additional leaseholds in this area, it could have a profound impact on the company," said Ray Reaves, president and chief executive officer.

GeoResources Inc.

GeoResources Inc. held a strong position in the Bakken play in the Williston Basin in early 2010, even though it drills through an operating partner.

In a February 2010 operations update, the company said it had participated in 42 wells drilled by its joint venture partner, Slawson Exploration Co., and held minor working interests in more than 140 wells in the Bakken/Three Forks trend.

The partnership ran four rigs in the play and continued to expand its acreage at that time.

Among the company's more impressive wells in 4Q 2009, the Stallion #1-2-12H produced at a rate of 2,523 boe/d on a 24-hour test, the Goldeneye #2-2H tested for 1,823 boe/d, and the Banshee #2-1H tested for 1,807 boe/d. GeoResources held interests of 11.7%, 4.34%, and 5.41%, respectively, in the wells.

The companies had 10 new wells producing, in completion, or drilling in 4Q 2009, and another four wells awaiting a rig move, drilling, or being completed in January and early February of 2010.

Frank A. Lodzinski, chief executive officer, said, "Our net production in the Williston Basin continues to increase with the ongoing success of this development program."

A December 2009 company overview said the company had recently acquired some 66,000 gross acres, and the joint venture operations gave GeoResources working interests from 10% to 18% in approximately 106,000 gross, 13,900 net, acres of Bakken properties. Within that acreage position, the company had 69,000 gross acres in Mountrail County, generally considered the sweet spot of the Bakken play.

GeoResources said the venture planned to drill some 60 wells during the 18 months from the beginning of 2010, and the 24-month budget called for 22 gross, 1.8 net, Bakken wells on proved locations, with potential for 263,000 boe in reserves for a net investment of US $3.4 million and finding and development costs of $13.03/boe.

In addition, the company planned 100 gross, eight net, wells on non-proved Bakken locations for a potential 2.56 MMboe in reserves for a net investment of $28 million with $10.94 in finding and development costs.

The company could add another 1.44 MMboe in reserves on non-proven infill drilling locations.

Those numbers don't count potential reserves in the Three Forks Formation immediately below the Lower Bakken.

The Bakken play earned the highest capital investment of any area in the company's portfolio.

In March 2010, GeoResources reported a joint venture with Resolute Energy Corp. in the Bakken trend. GeoResources had acquired some 61,000 gross, 42,000 net, lease acres in Williams County, N.D., and Resolute agreed to acquire a 45% interest in those properties. GeoResources retained another 45%, and the companies were looking for a third party to pick up the remaining 10%.

They planned to drill at least three horizontal wells to the Middle Bakken by the end of 2010 and to try to add to their acreage position. Three Forks, Madison, and Red River for-

mations provide alternate production potential.

Gulfport Energy Corp.

Gulfport Energy Corp. held Bakken properties, but it sold off the major portion of its holdings in North Dakota during 2009, and apparently has no plans for the remaining leases in 2010.

In a February 2010 presentation, the company said it sold 12,270 net acres of leases in the Bakken for US $13 million in the first half of 2009. It kept 6,740 net acres with interests in four gross wells, and it kept a 7.5% overriding royalty interest in the acreage it sold and reduced to its ownership interest after it turned over an 80% net revenue interest to the buyer. Those properties produced about 190 boe/d. During the second half of 2009, the company sold another 5,721 net acres, retaining about 900 net acres and interests in the four gross wells. In that property, it kept a 2.5% override in the sold acreage after giving up an 81% net revenue interest to the buyer.

During 3Q 2009, the company produced 9,313 boe from the Bakken. That compared with 354,757 boe from its southern Louisiana properties, and 51,636 boe from its Permian Basin holdings.

For 2010, the company said it planned to spend between $56 million and $62 million before any new asset acquisitions. That money would drill 19 to 21 wells at its West Cote Blanche Bay Field in the Gulf of Mexico, three wells at its Hackberry properties in Louisiana, and participation in winter drilling and seismic programs at the Grizzly oil sands project in Canada.

Helis Oil & Gas Co. LLC

Helis Oil & Gas Co. LLC boasted a growing presence in the Williston Basin as it worked its own properties and operated for other companies.

The company bid US $4,600/acre for a 200-acre parcel of land on the Fort Berthold Indian Reservation in McKenzie County, N.D., in 2008. It was the highest bid per acre in the auction.

One of its more aggressive activities opened late in

2007 when the company farmed in as operator on part of the Phoenix prospect owned by Sundance Energy Ltd., also on the Fort Berthold reservation. The two companies split part of the Phoenix properties off into an area of mutual interest and called it the South Antelope prospect.

They continue to work that prospect in which Australia-based Sundance has an option to take from 7% to 50% of any well drilled by Helis.

During 2008, the partners drilled 10 wells with an average initial potential of 633 b/d of oil and 604 Mcf/d of gas, or 734 boe/d, according to a March 2010 Sundance presentation.

That program helped Sundance grow its Bakken production from 200 to 3,000 b/d of oil.

The two companies held 27,355 gross acres at that time, and Helis held 23,179 net acres.

By March 2010, the companies had brought 12 wells on production from the property.

During 2010, Helis planned to drill eight gross wells, about 7.15 net wells. Sundance will contribute $5 million to the program from its 0.846 net-well position.

In early January 2010, Helis had 10 wells on confidential status on North Dakota records, according to Bakkenstocks.com.

Hess Corp.

Amerada Oil Corp., predecessor to Hess Corp., took a big risk when it drilled the first commercial oil well near Tioga in Williams County, N.D. That risk paid off as that well established the Williston Basin as an oil province and established a strong base of operations that grew into a worldwide operation for Hess Corp.

That 10,500-ft discovery on April 4, 1951, was on the Clarence Iverson farm, and the company had to drill through the Bakken zones to reach Silurian dolomite production.

By May 20 that year, the oil industry had leased some 30 million of the 44.8 million acres of land in North Dakota with a strong focus on Billings, Bottineau, Burke, McKenzie, Mountrail, and Williams counties.

Hess still operated its original Tioga and Beaver Lodge fields around the Clarence Iverson No. 1 well in 2010.

That wasn't the company's only contribution to the Williston. A year after the Iverson discovery, it drilled a well on the Henry O. Bakken farm, identified shale in the drill cuttings, and named the source formation after the owner of the farm.

The company still held a major land position in the basin and in the Bakken Shale play. Its Bakken properties, Gulf of Mexico (GoM) interests, and Permian Basin leases make up all of the Hess operations in the US, and it is one of the industry leaders in CO_2 enhanced oil recovery in the Permian Basin.

The company Web site said, "In North Dakota, we are the leading oil and natural gas producer. Following many years of maintaining production levels at several large company-operated units, including Beaver Lodge and Tioga Madison, our North Dakota asset is growing again with the development of our Bakken drilling program."

Most of the company's properties are east of the Nesson Anticline. From north to south, Hess calls them Avalanche, Impact, East Nesson, Red Sky, Passport, and Stampede.

According to a November 2009 presentation, Hess was an approximate 85% working interest owner in its position in the Bakken play. That position was substantial, with more than 500,000 net acres with Bakken potential.

At the time of the presentation, the company produced a net 10,000 boe/d from the Bakken and estimated its peak net production at 80,000 boe/d at some point in the future.

Hess found the same attractive properties in the Bakken that attracted other companies to the play. It represented a large captured resource with low-risk drilling. Like all resource plays, a mass-production manufacturing approach pays off and gives the play favorable economics.

Those characteristics fit the Hess working philosophy. Its exploration program focused on high-impact prospects in core growth areas led by a best-basin, best-play, best-prospect approach.

The company's 2010 production capital expenditure budget of US $2.4 billion was aimed at three world areas. One is its production drilling at its Okume Complex where it is operator offshore Equatorial Guinea in Africa.

Another focus was offshore, drilling production wells at the Shenzi project in the GoM, which came onstream in 2009, where it held a 28% interest; production wells at the Beryl Field offshore in the UK where it had a 22% interest; and production activity at Valhall offshore Norway where it owned a 28% share.

The third is the Bakken Shale in North Dakota. Hess planned to increase its rig count in that play from three,

near the end of 2009, to eight by the end of 2010. It also planned to expand its existing production facilities in the Williston Basin, including operations at its Tioga gas plant.

Expansion is in character for the company in the Williston Basin and the Bakken play. According to Jefferies & Company Inc.'s June 2008 "Resource Chronicles," Hess held 325,000 acres in Bakken-prospective land at the end of 3Q 2007. It raised that number to 400,000 acres by the end of that year, to 411,000 acres by the end of the first half of 2008, and reached the 500,000-acre mark in August 2008.

It had seven rigs working the Bakken at that time and planned to raise the count to 10 in 2009, but plunging oil prices pushed the company into a more conservative approach as it weighed the economics and waited for stability in prices.

At the end of the first half of 2008, the company was producing 8,000 boe/d from its Bakken properties. It also continued to hold properties that produce from the Mission Canyon Formation and properties with potential for Red River production.

Hess also proposed drilling six wells on a 2,560-acre unit, or 427-acre spacing in some parts of the Bakken play with dual-lateral wells, according to an April 2010 Jefferies & Co. report on Brigham Oil & Gas. If North Dakota officials approve that downspacing, it could raise reserves throughout the play.

A large potential for bonus income lies in the Hess Beaver Lodge Field. The US Department of Energy identified the field as a potential storage area for CO_2. That potential also could enhance Hess Bakken-formation production. EOG Resources Inc. has tested CO_2 tertiary recovery potential in its Parshall Field wells, and the experience Hess has with CO_2 recovery in the Permian Basin at the Seminole-San Andres unit could pay big dividends in the Williston Basin.

Hunt Oil Co.

Ray L. Hunt's Hunt Oil Co. has been a strong operator in the Williston Basin almost since the initial discovery well by Amerada Oil Corp. in 1951.

By November 1952, when the basin produced its millionth barrel of oil, Amerada had 74 wells, Hunt Oil nine wells, and Concord Energy LLC two wells.

Over the years, it drilled wells in Eleven Bar, Medora, Simon Butte, Blacktail, Rough Rider, Bicentennial, MonDak, Hofflund, Beaver Lodge, Ross, North Souris, Northeast Landa, Rival, Stoneview, Coteau, Grenora, and Keene fields in North Dakota, in addition to a host of wildcat wells.

In all, the North Dakota Industrial Commission listed 80 wells on the company's resume, including wells in some of the basin's oldest and largest fields.

Until it entered the Bakken play, however, all its attempts to complete a well below 10,000 ft were unsuccessful.

According to state records, the company entered the play in 2007, with wells in Parshall Field in Mountrail County, N.D., the most prolific field in the play near wells by the field's biggest player, EOG Resources Inc. It still drills most of its Bakken wells in Mountrail County.

By the end of the following year, Hunt Oil was the 10th biggest producer from the Bakken – according to state figures – with 634,417 bbl of oil produced from eight wells.

One of its larger wells, according to *Oil and Gas Investor* magazine, was the Henry 1-28H horizontal well in Mountrail County. That well produced at an initial rate of 1,129 boe/d.

It drilled the 3-5H Shell horizontal well in the Parshall Field in September 2009, completing the well at 14,499 ft measured depth in the Bakken. The well previously had been operated by EOG Resources.

Hunt perforated the Bakken from 9,600 to 14,380 ft, fractured the well, and tested the Bakken for 1,292 b/d of oil and 565 Mcf/d of natural gas.

Not all of its wells were in Mountrail County. In late 2009, it drilled the 10-3H Quill in Bailey Field in Dunn County to 19,000 ft in the Bakken, with a total vertical depth of 10,417 ft. It fractured the well and recovered 756 b/d of oil and 492 Mcf/d of gas from perforations between 10,922 and 19,000 ft.

In March 2010, IHS Inc. listed Hunt Oil as active at 22 wells in the Bakken, including wells permitted, reissued permits, wells drilling, and completions.

Jones Energy Ltd.

Jones Energy Ltd. – a privately held Texas oil and gas company with operations in the Texas Panhandle and western and southern Oklahoma – put in a successful bid to enter the Bakken Shale play in North Dakota.

The company formed a subsidiary, J/M Crusader Acquisition Sub. LLC, that successfully bid to buy all

the common stock of Crusader Energy Group through Chapter 11 proceedings in the US Bankruptcy Court. Funding for the purchase came from Metalmark Capital, various financial institutions, and debt capital.

Although the purchase improved Jones Energy's Texas Panhandle operations, according to Jonny Jones, founder and chief executive officer, it also gave the company positions in the Barnett Shale in the Fort Worth Basin, the Woodford and Barnett shales in West Texas, and the Bakken Shale in the Williston Basin.

Crusader Energy Group was formed in early 2008 when Westside Energy Corp. acquired Crusader and kept the Crusader name. At that time, the company ran seven drilling rigs and one operated in the Bakken trend.

It held 37,760 gross, 24,550 net, acres of Bakken leases and 300 MMcf of gas equivalent in proved reserves in the play, as well as 118 potential drilling locations along the Cedar Creek Anticline in southeastern Montana and southwestern North Dakota.

Plunging oil prices later drove Crusader to seek Bankruptcy Code protection from creditors while it reorganized. Sale of the company was part of that reorganization plan. Jones Energy bid US $289 million for the company.

Kodiak Oil & Gas Corp.

The sun sets on a North Dakota Bakken well, but it hasn't set on the most active oil play in the onshore Lower 48. *(Photo courtesy of Marathon Oil Corp.)*

Kodiak Oil & Gas Corp. likes plays with stacked pay potential, and it found a lot to like with its properties in the Williston Basin, where it concentrates on the Bakken while looking for profitable production in the Three Forks/Sanish, Red River, and Mission Canyon zones.

At the end of 2009, it had one drilling rig working the area and it was mobilizing a second rig.

In addition, the company set aside its largest capital expenditure budget to date, US $60 million, to work the Bakken play in 2010. Its 2009 budget was $21 million.

Of that $60 million, $43 million will go into 15 gross, 9.5 net, operated Bakken and Three Forks/Sanish wells in Dunn County; $12 million will drill seven gross, two net, non-operated wells in Dunn County and Three Forks wells in an area of mutual interest; and $5 million will go into other drilling in the basin.

Kodiak worked fast in the play. It prepared to drill its first Bakken well in June 2008 and started drilling its Dunn County, N.D., program in November the same year. By the end of 2009, it had nine producing Bakken wells providing a net 1,000 boe/d to the company.

In a February 2010 report on Bakken activity, the company said it had drilled and completed 10 producers, had two wells awaiting completion, and was drilling a 13th well.

In early 2010, the company experimented with three short-lateral horizontal wells with horizontal lengths from 4,200 to 4,800 ft. It previously had drilled wells with laterals as long as 10,000 ft.

The Moccasin Creek #16-3-11H, with a 4,729-ft lateral, tested for 1,419 boe/d (1,260 b/d of oil and 950 Mcf of gas) after a 12-stage fracture treatment. One of its long-lateral wells tested for 1,856 boe/d.

The company's work showed recovery rates per foot of lateral appeared to be greater in shorter laterals, but longer laterals offered a stronger rate of return because they touched additional reserves. Because of that, Kodiak planned to concentrate on longer laterals during 2010.

Kodiak also had started drilling on pads by that time, including a three-well pad at its Moccasin Creek Field and another three-well pad at its Two Shields Butte area to the north.

The company also planned wells in 2010 in McKenzie County, N.D., in an extension of Montana's giant Elm Coulee Bakken field, and it planned two Red River

wells in properties in Sheridan County, Mont., and Divide County, N.D., which also is prospective for Bakken, although Red River and Mission Canyon are the primary producing zones.

Meanwhile, the company didn't ignore the potential of the Three Forks/Sanish zone below the Lower Bakken.

"We continue to evaluate Three Forks production in the immediate area [Dunn County] and now expect to drill our initial test well sometime in the second quarter, 2010. A delay in the completion of an offsetting well drilled by another producer with whom we share data has led us to await their results. The delay they incurred was due to mechanical issues now remediated, and to inclement weather conditions. The well began producing in early February. While we are encouraged with the initial production data which further proves Three Forks potential in our immediate area, we have opted to defer the Three Forks test until the second quarter while continuing with our Bakken development drilling as scheduled," Lynn Peterson, Kodiak president and chief executive officer, said.

In a January 2010 presentation, Peterson said the company had 99,000 gross, 60,000 net, acres in the Williston Basin. Within that area, 55,000 gross, 35,000 net, acres were in Dunn County.

It held another 2,700 net acres in McKenzie County and 22,600 acres in the Sheridan-Divide county properties.

Lario Oil & Gas Co.

Lario Oil & Gas Co.'s fondness for low-risk prospects with strong development potential led it to unconventional oil and gas plays. Specifically, it embraced the Woodford Shale in Oklahoma for gas and the Bakken in North Dakota for oil, both trends that hold up under current lower oil and gas prices.

Additionally, Lario is building a significant acreage position in the horizontal Niobrara oil play in the Denver Basin.

According to the company, it acquired its first Bakken/Three Forks/Sanish lease in 2007, and by May 1, 2010, built that into some 195,000 gross, 35,000 net, acres, most of that land in the Mountrail County, N.D., Bakken sweet spot.

By May 2010, it had participated in, or acquired interests in, 155 producing Bakken/Three Forks/Sanish wells with working interests as high as 50%. It also had 10 wells under the drill bit and 43 more in various stages of completion. Year-to-date through May 10, 2010, Lario had participated in 53 gross, more than four net, wells with Brigham Exploration Co., EOG Resources Inc., Murex Petroleum Corp., Sinclair Oil Corp., Slawson Exploration Co., Whiting Petroleum Corp., and Zenergy Inc. as dominant operators. Brigham's Sorenson 29-32-1H provided the best completion at 4,335 b/d of oil and 4.5 MMcf/d of gas. Lario held a 4.3% stake in that well. Lario also held a 50% working interest in the Jerome Anderson 15-10H, a horizontal well that came in at an initial rate of 4,320 b/d of oil.

Lario said it was getting an average of six well participation proposals a week in early 2010.

By May 2010, the company's net production passed the 3,000 b/d mark with associated gas as a bonus.

Lario held interests in more than 90 sections and will be pooled into additional sections in the Van Hook/Big Ben and Reunion Bay fields in Mountrail County. It also became a 20% partner with Slawson, GeoResources Inc., Northern Oil & Gas Co., and others in the Windsor/Gulfport acquisition of 60,000 acres in the play in April 2009. That also gave it working interests in 59 producing wells, most of them in Parshall Field, one of the most prolific fields in the Bakken play.

In early 2010, Slawson had five rigs working the acreage and had completed the Stallion 1-1-12H well with a 36-stage frac treatment on its 9,182-ft lateral for an initial production of 2,561 b/d of oil and 1.29 MMcf/d of gas. Lario had a 14.62% working interest in the well.

In Parshall Field, Lario held working interests in 38 sections with EOG as the primary operator. EOG recently started an infill drilling program and a specific program aimed at the Three Forks/Sanish zone.

Lario had interests in 21 sections in the Ross Field area and interests in 36 more sections in the Alger area of Mountrail County. Lario turned over its operated locations to Brigham Exploration to take advantage of Brigham's track record for advanced technology and efficiency.

Lario had interests in 24 sections, before pooling, in the Stanley Field in Mountrail County, with EOG, Murex, and Fidelity Exploration & Production Co. as dominant operators.

It also held interests in 28 sections in the Sanish

Field area with Whiting as the predominant operator. Whiting is drilling infill and Three Forks/Sanish wells throughout the field.

Still another holding in Mountrail County includes 31 sections in Clearwater Field in EOG's Bakken Lite area. Lario turned over its operated property to EOG to leverage EOG's experience and technology. EOG announced 10 new locations on Lario acreage in that area in January 2010.

Lario also held property to the north in Burke County where Bakken activity is lighter.

The company continued to grow its holdings with leasing in the final stages at its Mustang project in Divide County, N.D., where the company found potential in both the Bakken and Three Forks zones.

Magellan Petroleum Corp.

Magellan Petroleum Corp., with operations in Europe and Australia, entered the Bakken play with its acquisition of an 83.5% share of Nautilus Poplar LLC in October 2009.

Nautilus held 23,000 acres of leases in the East Poplar unit and Northwest Poplar Field in Roosevelt County, Mont., and Magellan will continue to operate the properties under the Nautilus name. It bought the properties from White Bear LLC and YEP I, SICAV-FIS, arms of two of the company's directors, Nicolay Bogachev and Thomas Wilson.

Those properties contained proven developed reserves of 1.5 MMbbl of oil, net.

The acquisition, Magellan's first in the US oil market, included a 93.8% interest in the East Poplar unit and Northwest Poplar Field, both on the Poplar Dome, according to a May 2010 company presentation. The fields have produced 56 MMbbl of oil, but none yet from the Bakken.

The fields held additional potential in the Mississippian Charles and the Bakken Shale, according to Magellan.

"Our entry into North America is a fairly substantive one. We gain a highly-regarded technical staff and a key development position. The two fields purchased were first discovered in the early 1950s and have unrecovered oil reserves. Our neighbors there have had strong success with Tertiary development programs – we aim to establish a pilot program to determine the viability of those strategies at Poplar Dome and to drill infill sites in the fields," William H. Hastings, president and chief executive officer, said.

Magellan said its Montana Bakken formation had better reservoir properties than the massive Elm Coulee Bakken field some 20 miles to the southeast, and it planned to evaluate farm-out and joint venture opportunities to develop the play.

Marathon Oil Corp.

Marathon Oil Corp. works prolific properties around the world and measures risk and profitability to choose plays that meet its specifications for adequate returns. The Bakken Shale formation in North Dakota and eastern Montana is one of those plays.

The company's current position of 350,000 net acres makes Marathon one of the biggest operators in the oil trend. According to state figures, as reported on Bakkenshale.blog.com, it was the seventh-biggest producer in the play in 2008, with nearly 2.4 MMbbl of oil and almost 902 MMcf of gas from 80 wells.

At the end of 2009, Marathon held acreage in Dunn, McKenzie, McLean, Mountrail, and Williams counties in North Dakota and Richland County in eastern Montana. Those properties offered a net risked mean potential resource of some 150 MMboe, which included 100 MMboe from the Middle Bakken pay zone and 50 MMboe from other potentially productive zones.

The difficulty of efficient extraction from the Middle Bakken's mixed lithology makes it a natural laboratory for Marathon's reservoir-characterization, horizontal-drilling, and well-stimulation experts.

Marathon sank its first drill bit into the Bakken in May 2006, and tallied first production in August that year.

According to company figures, it had four rigs running ,in the play in early 2010, and planned to drill approximately 260 gross wells in the play over the next five years. Those wells could help the company reach its goal of 22,000 boe/d of net peak production by 2013.

In a March 2010 presentation, Clarence P. Cazalot Jr., Marathon's president and chief executive officer, offered insight into the company's activities in the Bakken.

With an average 83% net working interest in its Bakken wells, the company exited 2009 with net production of approximately 11,000 boe/d. To gauge the pace of Marathon's activity in the play, it produced 6,000 boe/d from about 50 wells in the Bakken in September 2008, and 90% of that pro-

duction came from its Hector/Ajax area in Dunn County, N.D., according to Jefferies & Company Inc.'s "Resource Chronicles."

The company drilled on 1,280-acre spacing, and its well-and-facilities cost amounted to approximately US $5.5 million/well. Oil from the basin sold at reliable, strong markets with respect to West Texas intermediate prices, and the company incurred a net development cost of between $16 and $20/boe.

Marathon optimized its property holdings in the play, both by acquisition and disposition. For example, it entered the play with 187,000 net acres in 2006, Cazalot said. It disposed of 37,000 acres in 2007 and 2008, and added another 110,000 acres through acquisitions between 2007 and 2010. It has added another 90,000 acres through "grassroots leasing" since 2006 to bring its current total to 350,000 acres.

The Bakken is composed of five distinct units in the play. Marathon's total net Bakken system included 4.5 Bboe of original oil in place, and the company estimated approximately 100 MMboe net mean recoverable resources from the Middle Bakken pay zone. That meant approximately 2% of the original oil in place is currently estimated to be recoverable.

Under its 2010 integrated technology program, Marathon had a suite of evaluation wells in progress, and was looking at flow capacity from its wells. Flow capacity analysis included stimulation and production testing.

It also was conducting fluid content and mobility studies through core analysis and formation-evaluation tests. The technology program called for rock dynamics studies with multimicroseismic testing (both on the surface and downhole), magnetic resonance imaging, sonic scanning, and imaging log analysis.

The analyses were expected to further unravel another potential Bakken-related pay in the basin known as the Three Forks. Operators are familiar with the Middle Bakken, and they're getting more familiar with the Three Forks/Sanish zone below.

According to Bakkenshale.blog.com, Marathon drilled the Darwin 14-35H horizontal well in North Murphy Creek Field in Dunn County, N.D., to the Lower Lodgepole Formation, immediately above, and sourced by, the Upper Bakken Shale. The well, drilled with a 5,500-ft lateral, tapped a limestone layer about 50 ft higher than the Middle Bakken and showed an initial potential of 160 b/d of oil with no fracture treatment.

On all its properties throughout the world, Marathon's production capital spending is projected to be $1.8 billion in 2010, up 21% from 2009. More than 40% of this year's production spending is targeted for three projects. It will build its satellite fields around the Alvheim/Vilje development offshore Norway and advance work on the deepwater PSVM development in Block 31 offshore Angola. The third major project on the priority list is Marathon's plan to drill or participate in an additional 75 wells in the Bakken play. Additionally, in the Gulf of Mexico, Marathon is targeting first production from its Droshky development in mid-2010.

Murex Petroleum Corp.

Murex Petroleum Corp. was one of the first companies to spud a Bakken well, starting in 2005 in North Dakota, in the latest revival of the resource that has become the biggest oil play onshore in the Lower 48.

By April 2008, it had 21 producing Bakken wells, according to an Associated Press interview with Donald Kessel, vice president, who started looking at potential production in the late 1990s when the Meridian Resource Corporation subsidiary of Burlington Northern was drilling horizontal wells to the formation. By the middle of 2009, that total had climbed to 26 producing Bakken wells.

The company has operations throughout the producing area of North Dakota, as well as operations in South Dakota and Montana.

The company was named the 10th largest Bakken producer in 2008 with 1.2 MMbbl of oil and 571 MMcf of natural gas from 110 wells, according to state figures reported on Bakkenshale.blog.com.

It drilled its own properties but also farmed in to properties owned by other companies, including Northern Oil & Gas Co.

In 2009, it was the ninth biggest producer in North Dakota, with 140 wells in North and South Dakota, Montana, and Wyoming, and at that time, was concentrating on horizontal drilling on the Nesson Anticline in Williams County, N.D.

On its own property, Murex liked to drill wells with the first and middle names of company employees, and controlled more than 34,000 net mineral acres through its affiliated companies.

Among company wells, it drilled the 2 Alfred Brown

in Camel Butte Field to the Bakken in McKenzie County, N.D. It began drilling on Jan. 22, 2010, and reached total depth on Feb. 10, 2010. Results of that vertical well were held confidential under North Dakota rule options.

In Mountrail County, it drilled the 1-12H Thomas Patrick horizontal test in Sanish Field with the Bakken as the target zone. Precision Drilling rig #645 spud the well on Aug. 10, 2009, and the well reached total depth at 9,695 ft in the Middle Bakken on Sept. 9, 2009.

Murex fractured the well in a horizontal interval between 10,313 and 19,192 ft. It completed the well on Nov. 15, 2009, for an initial potential of 1,380 b/d of oil, 551 Mcf/d of gas, and 81 b/d of water.

The 27-34H Ryan Thomas was one of the earlier Murex wells in Capa West Field. It spud the horizontal well on Sept. 27, 2007, and completed it as an openhole well with perforations between 10,177 and 19,195 ft. The well tested for 223 b/d of oil and 96 b/d of water from two laterals after completion on Nov. 10 that year. That was a new pool discovery in the field.

A year later, it drilled the 9-4H Kayden Cole in Tioga West Field, another horizontal Bakken well. Cyclone Drilling Inc.'s rig 20 spud the well on Nov. 11, 2008, the well reached total depth on Dec. 3, 2008, and the company completed it as an openhole well with Bakken perforations between 10,064 and 19,110 ft, according to IHS Inc. records.

Again, without a fracture treatment, it produced 233 b/d of oil, 279 Mcf/d of gas, and 80 b/d of water.

Newfield Exploration Co.

Newfield Exploration Co. changed its focus during 2009 to concentrate more on the liquids side of the oil and gas business where oil prices fetch a higher value, relative to their energy quotient, than natural gas.

That change fit right in with the company's increasing land position and drilling activity in the Bakken play in North Dakota and Montana.

Newfield held a lot of resources, the company pointed out at a March 2010 presentation. It had offshore and onshore assets with conventional and unconventional resources. In short, it had a lot of opportunities to high-grade its assets when times got tight in the industry.

The decision on the direction of its investments showed clearly in its acquisition of 500,000 net acres in resource plays in the six months before the presentation. By the end of 2009, 80% of its proved reserves were in resource plays, primarily in the Woodford Shale, the Granite Wash, and Monument Butte in Utah.

By the end of 2008, the company had 473,000 net acres in the Williston Basin, and it had drilled eight successful wells. It originally planned to drill 20 to 40 Bakken wells in the basin in 2009, but the drop in product prices lowered that goal to 10 to 12 wells with a one-rig program in 2009. For 2010, the company plan called for a three-rig drilling program to increase production by 40%.

By 1Q 2010, that land position had grown to 498,000 net acres in the basin, with 190,000 acres on the rolls for exploitation and development, and the other 310,000 acres lined up for exploration.

The shift toward liquids put even more emphasis on Monument Butte. It also put focus on the Eagle Ford Shale – a gas shale, but with a high liquids content – and on the southern Alberta Basin, on Malaysia, on China, and on the Williston Basin.

Even though Newfield was one of the top leaseholders in the Bakken play, it didn't make the list of top 30 producers in North Dakota in 2008 because that wasn't a prime focus area at the time. That may change.

In early 2010, the company operated Big Valley Field on the border of Divide and Williams counties in North Dakota, where it has 51,605 net acres.

It had another 14,400 net acres in Cartwright Field, which it operated on the Montana-North Dakota border. Other operated fields include Catwalk, with 25,000 net acres, and Watford South, with 7,800 net acres. It also had 9,700 net acres in the Aquarium joint venture with Whiting Petroleum Corp., which both companies operate, and it shared operations with other operators in the Westberg prospect, where it held 8,050 net acres, and Lost Bear, where it had 7,740 net acres.

Lost Bear is on the McKenzie-Dunn counties border and is prospective for the Three Forks/Sanish Formation, in addition to the Bakken. Newfield had an approximate 57% interest in the field.

Newfield and Concho Resources Inc. each held a half interest in the Westberg prospect in Williams County.

On the Montana side of the play, Newfield controlled 54,000 net acres in giant Elm Coulee Field, where it operated some wells and other operators drilled some wells.

The company estimated its Williston development and exploitation properties represented an unrisked

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resource potential of more than 100 MMboe, and its exploration properties has an unrisked potential of 240 MMboe, when it had 473,000 acres.

At the same time, risked potential for the development and exploitation area gave the company 240 drilling locations with 52 to 67 MMboe in risked potential, with 52% in the Bakken and 41% in the Three Forks/Sanish. The exploration acreage included 192 locations with 24 to 30 MMboe in risked potential.

Northern Oil & Gas Co.

Northern Oil & Gas Co. may be the biggest beneficiary of the Bakken/Three Forks play that has never drilled a well.

The company assembled a sizable packet of land in the sweet spot of the Bakken trend in North Dakota, and allowed veteran operators to farm in to the properties.

In a December 2009 presentation, the company said it held about 250,000 gross, 85,000 net, acres in the play, and it had participated in 160 gross Bakken or Three Forks completed wells and had another 27 gross wells in the drilling and completion stages. It also claimed a 100% success rate in the play.

By mid-year 2009, it held 130 net drilling locations on 640-acre spacing, and twice that many on 320-acre spacing.

During the first half of 2009, its partners had drilled eight wells to the two formations. The company had average net production of 600 boe/d in 2Q 2009, finished 3Q 2009 producing 1,200 boe/d, and at the time of the December presentation, had 1,500 boe/d in net production.

Its strategy, which has been working well for Northern, is simple; continue to exploit the Bakken/Three Forks as a non-operator partner with experienced operators, and continue to acquire acreage as opportunities arise.

Those opportunities have occurred often. It picked up 3,500 core net acres in leasing programs. It gained 2,000 net acres in leasing option programs. It added 12,000 net acres in the November 2009 North Dakota lease sale on a 50-50 basis with Slawson Exploration Co. It acquired 11,000 net acres in Slawson's Big Sky Bakken program in Richland County, Mont., where the first well spudded in November 2009, and it acquired 13,000 net acres with its half interest in Slawson's Anvil properties in Williams County, N.D., and Roosevelt County, Mont.

Its North Dakota partners have treated Northern well. In January 2009, Questar Corp. drilled a Bakken well in McLean County for an initial potential of 949 boe/d. Slawson followed up in February with a Mountrail County well that tested for 1,117 boe/d. Hunt Oil Co. drilled another Mountrail County well for 2,066 boe/d. Continental Resources Inc. added its part in May 2009 with a 661 b/d well near the border between Divide and Burke counties. Kodiak brought in a 1,394 boe/d that same month in Dunn County.

EOG Resources Inc. had two wells on the select list – a 1,170 boe/d well in Mountrail County in June 2009 and a 1,585 boe/d well in the same county in November.

Brigham Exploration Co. drilled a Three Forks/Sanish well in Mountrail County for 2,010 boe/d, and Continental drilled another well to the same zone in Dunn County in November for 1,095 boe/d. Another partner, Marathon Oil Corp., completed a Mountrail County Bakken well in August for 1,150 boe/d.

In its year-end 2009 report, Northern said its properties held 6.1 MMboe, a 700% increase over reserves at the end of the previous year. That was figured on a price of US $53/bbl for oil and $3.93/Mcf for gas.

At an oil price of $71.82/bbl and a gas price of $5.07/Mcf, reserves climbed to 10.5 MMboe.

Those reserves came from drilling only about 10% of the company's acreage.

Northern produced 282,212 boe during 2009, up from 51,542 boe the previous year, but that was from all of its properties, not just the Bakken/Three Forks portion, that made up the lion's share of its holdings.

In spite of flat oil prices, action accelerated rapidly in the Bakken play. Northern said the North Dakota Industrial Commission reported 99 rigs drilling in the Bakken/Three Forks in March 2010, up from 30 rigs in May 2009. More rigs drilling the basin means more rigs drilling Northern properties.

For example, Slawson is working five rigs in the basin on properties acquired in Mountrail County from Windsor Bakken LLC. It planned to drill 60 wells on those properties in the 14 months starting in January 2010, and Northern's average interest in the wells was about 20%.

Operators working with Northern also have advanced their technology. Slawson's initial Mountrail County wells used nine frac stages on 640-acre spacing. Its

most recent wells on the same spacing get 18 to 22 fracture stages, resulting in 60% higher production in the first 60 days, Northern said.

Slawson's latest well in 2010 – the Stallion 1-1-12H, in which Northern held a 23% interest – used 36 frac stages for an initial production rate of 2,735 boe/d and a first-20-day average of 1,525 boe/d.

Recent production rates should pay out a well in only three months.

Northern planned to participate in approximately 15 net Bakken and Three Forks wells in 2010 with some $67.5 million in drilling capital. That anticipated an average drilling cost of $4.5 million/well.

Oasis Petroleum LLC

Former senior managers of Burlington Resources Inc. formed Oasis Petroleum LLC after ConocoPhillips Co. bought their former employer. They targeted the Bakken and Three Forks formations immediately with the help of cash from EnCap Investments L.P. in 2007, found a rig, and started drilling.

By 2008, the company had an agreement to drill wells in partnership with MDU Resources Group, Inc., a large North Dakota pipeline and utility company with its own exploration and production arm.

In March 2010, the company announced its intention to go public with a US $350 million initial public offering, and supported the offering with an impressive track record in the play.

By the end of 2009, Oasis had 292,000 net acres in the Williston Basin, 85% undeveloped.

That included 159,491 net acres in its West Williston project area where it had 268 gross, 106.5 net, drilling locations. For 2010, it planned 41 gross, 18.8 net, wells on the acreage to reach estimated net proved reserves of 5 MMboe. Production had reached 1,106 boe/d.

It held another 124,004 net acres in its East Nesson project area with room for 113 gross, 57 net, drilling locations. It planned to drill 13 gross, 7.4 net, wells in 2010 using $47 million in drilling capital to reach 3.9 MMboe in estimated net proved reserves. Daily production stood at 1,016 boe/d.

In its Sanish project area, it controlled 8,747 net acres and locations for 88 gross, 9.6 net, well locations. It planned to use $22 million in capital to drill 37 gross, 3.8 net, wells in 2010, with a goal of finding 4.3 MMboe in estimated net proved reserves. It produced 792 boe/d from the area at the end of 2009.

Its total capital expenditures, according to its filing with the US Securities and Exchange Commission, will reach $220 million in 2010, including $134 million for drilling and completion of operated wells, $45 million for drilling and completing non-operated wells, $15 million to maintain and expand leases, $5 million to build infrastructure and support production, and $21 million in unallocated capital which it can use for additional drilling or leasing.

It built its position in the Williston Basin quickly. It started with a 175,000-net-lease-acre acquisition in June 2007. That property had 1,000 boe/d of production and remained the core of the West Williston properties.

In May the following year, it entered a farm-in agreement that let it earn or acquire 48,000 net lease acres. That was the initial East Nesson property.

It followed up in June 2009 with a 40,000-net acre acquisition, with 800 boe/d of production that consolidated East Nesson acreage and established its Sanish project area.

In September 2009, it picked up another 46,000 net acres of leases with 300 boe/d of production to further consolidate the East Nesson area.

At the end of the year, it had estimated net proved reserves of 13.3 MMboe.

As an indicator of its activity, the company drilled four wells from the end of 2009 to mid-March 2010, and had one rig working in West Williston and another in East Nesson.

It drilled one of its more recent wells on Northern Oil & Gas Co. property in Burke County, N.D. The Edwards 5992 44-10 horizontal well, in which Northern kept a 21% interest, tested for 478 boe/d after a 28-stage frac treatment.

Panther Energy Co. LLC

Panther Energy Co. LLC, majority owned by the Southern Ute Indian Tribe Growth Fund, entered the Bakken trend in North Dakota slowly, by drilling wells for Basic Earth Science Systems Inc.

The company specialized in horizontal drilling exploration in unconventional resources and had properties in Texas, Oklahoma, Montana, California, and Arkansas.

Basic Earth held the Banks prospect in eastern McKenzie County, N.D., and brought in Panther to drill

two wells on its property.

Panther first drilled the Wil E. Coyote 9-2H on the 13,000-acres Banks prospect after Basic Earth signed over rights to its 20% share of the prospect. Panther agreed to carry Basic Earth's costs on those two wells.

The companies originally planned to drill the well to the Bakken Formation with a horizontal lateral, but the vertical pilot hole showed attractive cuttings in the Three Forks, so they changed the target zone. When the well came off tight-hole status, the companies said it recorded an initial potential of 486 b/d of oil, 500 Mcf/d of gas, and 202 b/d of water, and had averaged 185 b/d of oil, or approximately 4,400 bbl of oil, between the time it went on production in February 2009 and late March 2009.

Panther also drilled the Roscoe 2H-8 horizontal well in the program. That well, completed in June 2009, tested for 534 b/d of oil, 1.18 MMcf/d of gas, and 122 b/d of water from a horizontal Bakken lateral. Basic Earth kept a 6.25% interest in both wells.

Peak Energy Resources Inc.

Peak Energy Resources Inc. worked its Bakken properties in North Dakota through its Peak North Dakota LLC affiliate, a company that has increased its activity level in the popular play.

The company drilled its first well, the Takakwitha 9-24H, on the Fort Berthold Indian Reservation in Dunn County, N.D., about 15 miles southwest of prolific Parshall Field. It was the first horizontal Bakken well on the reservation, as well. That early 2008 well came in at about 1,000 b/d of oil as part of Mandaree Field, according to the *Rocky Mountain Oil Journal*.

In March 2010, the company held approximately 54,000 net acres in the Bakken/Three Forks play, most of that property on the Fort Berthold Reservation where it began acquiring acreage in late 2007. By December 2009, it had drilled and completed 12 successful wells, 10 to the Bakken and two to the Lower Three Forks.

In January 2010, the company applied to the North Dakota Oil & Gas Division of the North Dakota Industrial Commission to extend field boundaries and establish 640-acre spacing units with one horizontal well on each spacing unit in the Spotted Horn-Bakken pool, the Antelope-Sanish pool, the South Fork and/or McGregory Buttes-Bakken pool, and the Eagle Nest-Bakken pool.

At that time, the company had three wells on the state's tight-hole list, the Fredericks 23-31H, the Red Tipped Arrow 33-11H, and the Schilke 8-24H.

Penn Virginia Corp.

When it comes to unconventional resources, Penn Virginia Corp. is no shrinking violet.

It has coalbed methane properties in Appalachia and Oklahoma, and works the Marcellus and Lower Huron shales in Appalachia. It's active in the Haynesville Shale in East Texas and the Woodford Shale in the Arkoma and Anadarko basins of Oklahoma. It plays the Fayetteville Shale in Arkansas and the Selma Chalk in Mississippi.

It also likes the Bakken Shale play in North Dakota, with its high potential pay in the dolomite section between the upper and lower shales, but it suspended activity in the play. IHS Inc. reported no open permits in the Bakken by the company during the past 12 months.

The company finished 2008 with two wells, and originally planned six wells for 2009 with a goal of drilling 40 wells on its property.

In 1Q 2009, it participated in one gross, 0.02 net, wells in the Bakken.

The company held some 57,000 net acres in Dunn and McKenzie counties that it operated with a 35% interest with unnamed partners, and had just completed its first horizontal well, the Sickler 22-1H, in Dunn County in mid-2008, and committed to another, according to Jefferies & Company, Inc.'s June 2008 "Resources Chronicles."

The second operated well tested for an initial potential of 666 boe/d, and its third well, operated by another producer, tested for 544 boe/d.

Penn Virginia Corp. estimated its unrisked exploratory potential in the Bakken at 80 Bcf of gas equivalent.

Petro-Hunt LLC

William Herbert Hunt combined opportunity, knowledge, experience, and technology in bringing his Petro-Hunt LLC to the Williston Basin, showing the same kind of perception his father, H.L. Hunt, displayed when he bought the Daisy Bradford No. 3 – the discovery well for the supergiant East Texas Field from Columbus Marion "Dad" Joiner.

Petro-Hunt had better technology to refine its play. Its Otto Boss 18-1 in Williams County, N.D., was the first

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dual whipstock re-entry out of 5½-in. casing in North Dakota. At 7,172 ft, it was the longest lateral drilled out of a re-entry well by April 1998. And it was the first four-lateral well ever drilled in North Dakota.

The company also made some opportune acquisitions. Petro-Hunt bought Chevron Corp.'s properties in the Williston Basin for US $48 million in 1992, and bought Texaco's properties for $22 million in 1995.

It has drilled a lot of wells in North Dakota, and it's still drilling aggressively, but it's most remarkable well probably is the USA 2D 3-1H in section 2-153n-95w in Charlson Field, about 25 miles from giant Parshall Bakken Field in McKenzie County.

The Petro-Hunt well didn't stop at the Bakken; they went straight through to the next lower formation – the Three Forks/Sanish. When Petro-Hunt discovered the well in October 2006, it tested for 729 b/d of oil, 785 Mcf/d of gas, and almost no water, according to the Bakkenshale.blogspot.com Web site. The well probably paid for itself in six months.

Petro-Hunt calls the well a Bakken well, but it might be a Three Forks/Sanish well.

Already one of the largest independents in the world, it also is one of the largest independents in the Williston Basin. In 2008, it was the ninth biggest producer in North Dakota with totals of 1.56 MMbbl of oil and 3.1 Bcf of gas from 157 wells.

Among recent wells, Credo Petroleum Corp. participated with a 10% interest in the Petro-Hunt 148-94-17D-08-1H. Credo reported in February 2010 that the well tested for 1,267 b/d of oil and 1.24 MMcf/d of gas, or the equivalent of 1,474 bbl of oil.

Petro-Hunt completed the well on the Fort Berthold Indian Reservation with an 11,150-ft vertical hole and a 9,200-ft lateral in the Middle Bakken with a multistage frac treatment.

The vertical section also reached the deeper Three Forks/Sanish zone. Companies drilling nearby are evaluating that zone for commercial production.

Credo scheduled a second well with Petro-Hunt, the 147-94-3A-10-1H well, four miles to the southeast of its initial well. Credo will hold an 18.75% working interest in that well.

Questar Corp.

Questar Corp., through its Questar Exploration & Production unit, prides itself on being a successful natural gas explorer in the Rocky Mountains and the Midcontinent. That focus turned the company's sights to gas, but it hasn't neglected oil in the Bakken Formation in North Dakota.

According to a March 2010 presentation, its growth drivers are its Haynesville properties in Louisiana and its Pinedale leases in southwestern Wyoming.

The Bakken, Granite Wash in the Texas Panhandle, and the Woodford/Cana in Oklahoma offer "additional growth from emerging resource plays," the company said.

At that time, it controlled 46,000 net acres in the Haynesville; 17,872 gross acres in Pinedale, with 1,400 locations and 1.3 Tcf of gas equivalent in proved reserves; 26,000 net acres in the Woodford/Cana Shale; and 23,200 net acres in the Granite Wash.

It held 80,000 net acres in the Bakken play in an area of production immediately south of the Parshall/Sanish Field – the top field in the play – with initial potentials from 750 to 3,000 boe/d, and immediately northeast of Marathon Oil Corp.'s Bailey Field with initial potentials from 500 to 1,000 boe/d.

Although Questar had started drilling only five wells by March 2010, its initial potentials fell between potentials in the fields to the north and south.

It completed three wells in the Bakken. The MHA 1-13-14H tested for 1,405 boe/d from an 8,915-ft lateral. Questar had an 88% working interest in that well. It produced 27,119 boe, or an average 904 boe/d, during its first 30 days onstream.

Its MHA 1-18H gave the company an initial potential of 949 boe/d from a 4,122-ft lateral. It had a 68% interest in that well. It had a 78% working interest in the MHA 1-08H, which produced 841 boe/d from a 4,992-ft lateral.

The other two wells hadn't been completed at the time of the presentation.

According to Questar, it drilled its Bakken wells with laterals from 5,000 to 10,000 ft at a cost between US $5.5 million and $6.5 million to completion.

It will run one operated rig in 2010, and at least one of its wells will test the Three Forks Formation. It had working interests in 27 producing wells in the Bakken.

Quicksilver Resources Inc.

Quicksilver Resources Inc. would never be classified as a follower in the industry. It was among the first to take up the unconventional resources banner and holds a

strong inventory of unconventional properties in the US and Canada.

Its first look at the Bakken upholds that reputation. The company is looking for Bakken production in areas not generally tested by the rest of the industry.

In a March 2009 presentation, the company said it had 165,000 acres in the Barnett play in the Fort Worth Basin with more than 3 Tcf of gas equivalent in unbooked resources. It had another 78,000 net acres in the Green River Basin. It held 350,000 acres of Horseshoe Canyon coalbed methane properties with 253 Bcf of gas equivalent in reserves in Alberta.

The company also is looking at the Bakken in its 130,000 acres of properties in Cut Bank Field on the Sweetgrass Arch in northwestern Montana, and on its 130,000 acres in the Horn River Basin in northeastern British Columbia.

Nearly all present Bakken production comes from western North Dakota, eastern Montana, southeastern Saskatchewan, and southwestern Manitoba, but Quicksilver was an early operator in bringing the play to northwestern Montana.

During the company's 4Q 2009 conference call, recorded by Seeking Alpha, Glenn Darden, president and chief executive officer, said Quicksilver's land with Bakken potential in Montana is held by production from the shallow Cut Bank sand in Glacier and Toole counties.

He added, "We will be monitoring results from wells offsetting our block as close as a mile away, and at the same time, implementing a plan to drill a couple of horizontal wells to test the Bakken and other formations on our block. We have excellent well control to map the Bakken in this area. What could be significant to the economics is the shallow depth that will hit the Bakken between 3,000 and 4,000 ft.

"In our shale exploration in the Horn River Basin (of British Columbia), our focus has been on the Devonian Muskwa and Klua shales. As part of our early exploration, we have sidewall cored the upper formations, as well as the deeper shales. In the coring, we have seen very good oil shows in the Bakken-Exshaw section at approximately 4,000 ft. We have had these shows in all four shale wells we've drilled to date.

"Analysis of the core samples have shown an 80-ft section to be in a high mature oil window in terms of thermal maturity. All of the cores showed mobile oil. We will re-enter a seismic monitoring well later this year and drill a horizontal leg for initial testing of this Bakken-Exshaw zone, and look forward to fully evaluating this added potential to our large lease block up in Northeast British Columbia," Darden said.

Red Willow Production Co.

The Red Willow Great Plains LLC arm of Red Willow Production Co. has an active Bakken drilling program in Montana and North Dakota.

Red Willow is the oil and gas production affiliate of the Southern Ute Indian Tribe.

Although information about the company's operations is held tight, the company took out a permit in September 2009 to drill a Bakken horizontal wildcat in Roosevelt County, Mont. That was the Iron Bear 1-1H. In December 2009, it acquired a permit to drill the Turner 25-1H, a Bakken wildcat in Daniels County, Mont.

It had one well on the confidential list for North Dakota. That was the Eagle 14-30H horizontal well.

In addition, Red Willow signed an agreement in October 2009 to farm in for a half interest of Stetson Oil & Gas Ltd.'s 12,696 acres of freehold land in North Dakota, and for 60% of that company's 8,185 acres of land on the Fort Berthold Indian Reservation in North Dakota.

Under the agreement, Stetson would operate wells on the freehold land and Red Willow would operate on tribal land as the companies worked their commitment to drill three initial wells.

Stetson started drilling the first joint well on the freehold land in August 2009 as operator with a 48.75% interest, and Red Willow applied for a permit to drill its first well five miles to the southeast at about the same time.

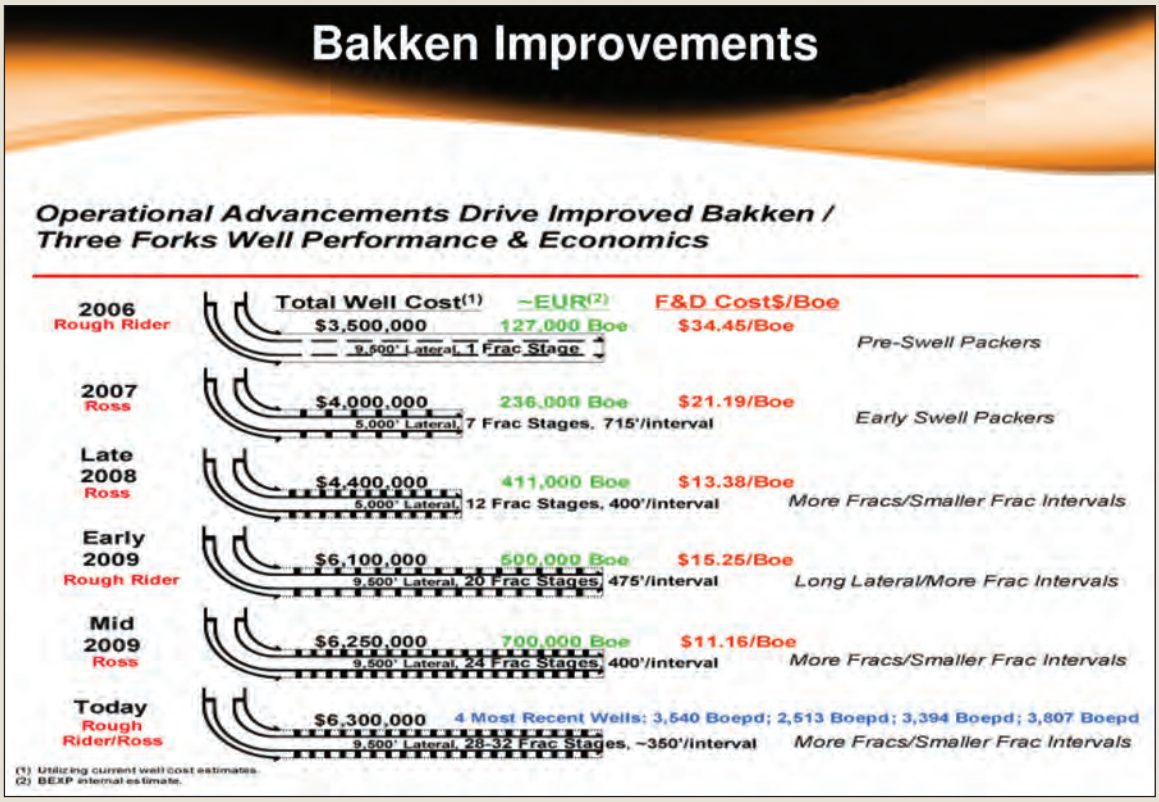
By February 2010, Stetson had installed a pumpjack on its MHA-1-11H-148-90 horizontal well and produced about 50 b/d of oil, and the companies were evaluating Bakken potential. By that time, it had produced 1,470 bbl of oil.

Stetson and Red Willow also agreed to acquire some 220 miles of existing 2-D seismic data to help locate high-potential drilling sites.

Resolute Energy Corp.

Resolute Energy Corp.'s veteran management team, already locked in to two large fields with long production histories, has turned its attention to the Bakken in North Dakota.

The Resolute team built HS Resources, Inc., a company that started business in Denver with an initial



Time and technology led to longer laterals with more fracture stages. They added expense to Bakken wells but resulted in significantly better returns for operators. *(Diagram courtesy of Sundance Energy Ltd. from Brigham Oil & Gas)*

public offering of US $155 million in 1992, and sold the company to Kerr-McGee Corp. nine years later for $1.8 billion.

After forming Resolute, those managers acquired shares in the giant Aneth Field of southeastern Utah and in the Highlight gas field in Wyoming to form a foundation of steady income.

Early in 2010, Resolute announced a joint project with GeoResources Inc. to develop property in the Bakken play.

GeoResources had acquired about 61,000 gross, 42,000 net, acres in Williams County, N.D., giving Resolute approximately 20,000 net acres in the play. Under the plan, Resolute and GeoResources each will own 45% of the project, and they plan to bring a third party into the deal for the remaining 10% working interest.

They planned to drill three horizontal Bakken wells by the end of 2010. Resolute already allocated $22 million to $24 million to Bakken activity for the year. The companies share 65 potential Bakken locations, which also have potential for production from the Three Forks, Madison, and Red River zones.

When the companies signed their agreement, Nicholas Sutton, Resolute chief executive officer, said, "We are particularly excited about our recently-announced entry into the Bakken play in North Dakota. Our initial acreage position and our planned cooperative effort with GeoResources, Inc. give us encouragement that this area will become a growing, oil-prone focus area for the company."

Rosetta Resources Inc.

Rosetta Resources Inc. shunned the traditional Bakken territory in Saskatchewan, Manitoba, North Dakota, and eastern Montana to stake a strong position in leases with Bakken potential in the Alberta Basin of northwestern Montana.

By the end of 2009, the company had accumulated some 240,000 net acres in the area, far removed from its current production in the Denver-Julesburg, San Juan, and Greater Green River basins in the Rocky Mountains.

According to Rosetta, the Alberta Basin play is a westward analog to the Bakken/Three Forks play in the Williston Basin.

It picked up an option on 200,000 net acres on the Blackfeet Indian Reservation in Montana in 2009, and

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drilled one vertical and one horizontal well. It added another 46,000 net acres to its land position, and drilled another well to confirm the presence of oil in the Banff, Bakken, Three Forks, and Nisku formations.

It drilled one well and staked another in Shelby County and drilled two others in Glacier County by April 2010 to determine between 13 and 15 MMboe/sq mile of resource in place.

Two of the drilled wells were on strike and 28 miles apart, while the other was eight miles downdip. It planned additional assessment during 2010, including fracture treatments on the two 2009 vertical wells.

Samson Oil & Gas Ltd.

Samson Oil & Gas Ltd. manages a strong portfolio of oil and gas resources from its home base in Australia, including a position in the Bakken in North Dakota.

Samson had properties concentrated in the Rocky Mountain states, and planned to expand its operations into the Texas Gulf Coast as it sought to balance prolific production with long-life assets.

According to a February 2010 presentation, Samson had only one well on the way to production in the Bakken – the Gene 1-22H. The company completed drilling on the well at 11,547 ft, and after identifying oil and gas shows at the toe of the horizontal section, ran production liner with swell packers and was ready to fracture before production testing. It planned 16 340-ft fracture treatments.

An April press release added that the well – in which Samson held a 30.6% working interest – tested at a rate of 1,112 boe/d from the toe of the horizontal section, but flowback results indicated a sand plug in the well bore. After drilling out frac plugs near the heel, the company saw an immediate pressure response. In the eight hours following completion, the company tested the well for 2,406 b/d of oil and 3.18 MMcf/d of gas.

Zavanna, LLC, the operator of North Stockyard Field, first drilled the Harstad #1-15H and completed it in the Bluell Formation where it produced at rates from 90 to 100 b/d of oil. It followed up with the Leonard 1-23H in 2008 with Samson as a 30.6% partner. That well showed low porosity and permeability in the Bluell. The field partners decided to go deeper with a 6,000-ft leg in the well, even though the Bakken hadn't been tested in the field. The partners decided at that time, if the Leonard well was a success, they would complete five additional wells in the field within two years in the Samson acreage around the field. If those wells were successful, the partners would form a unit over the full producing area.

After a re-fracture treatment with stronger proppant, the Leonard well tested for 305 b/d of oil and 500 Mcf/d of natural gas.

Samson held a 32% interest in the Williams County, N.D., field area and a 30.6% interest in the Gene #1-22H well.

During the two years since the completion of the Leonard well, fracture treatments improved significantly, and the companies are counting on better production from the Gene well.

In all, the field held 489,000 bbl of proved and probable reserves with a net present value, discounted at 10% a year, of US $8.3 million. Samson held an interest in 3,303 acres in the area.

The companies planned to keep one rig running during 2010 in the field and in the surrounding area.

Samson Resources Co.

Samson Resources Co. of Tulsa, Okla., mounted an active drilling campaign in the Williston Basin as it reached for high pay rates in an outlying portion of the Bakken play.

The privately owned company doesn't release much information about its position in the play, but information from state records helps fill in the blanks.

According to the North Dakota Industrial Commission, Samson Resources was the 15th largest producer from the Bakken in 2008, with 275,353 bbl of oil from 22 wells.

In North Dakota, a company can declare a well confidential, or a tight hole, and hold information about the well for two years.

Samson Resources has been an active driller in the play long enough that some of those wells have emerged from the tight-hole period.

Two wells came off confidential status in April 2008. One well was the Hanisch 28-163-98H in section 28-163n-98w in Divide County. That well tested for 58 b/d of oil and 58 b/d of water. The other well, the Sparks 4-162-98H in section 4-162n-98w, also in Divide County, came in at 197 b/d of oil and 47 b/d of water.

In February 2008, its Holm 33-163-98H, in Divide County, tested for 102 b/d of oil, according to IHS Inc.

In January 2008, the company said its Haugland 31-

163-98H in section 31-163n-98w in Divide County tested for 261 b/d of oil and 104 b/d of water.

In October 2008, Samson Resources joined Fidelity Exploration & Production Co., The Discovery Group, Idaho National Laboratory, and Colorado Energy Research Institute with Colorado School of Mines in a three-year study sponsored by the National Energy Technology Laboratory to accurately assess Bakken potential on a subregional basis. The study also planned to build a 3-D reservoir model of Elm Coulee Bakken Field in Montana and then move to Parshall Bakken Field in North Dakota.

IHS Inc. said the North Dakota rig count rose to a record 90 in September 2008. At that time, state regulators approved a 3-D seismic study of the 330-sq mile Blooming Prairie Field area in northern Divide County along the border with Canada. Samson Resources had been working the Bakken/Three Forks in that area since early 2007 and discovered Blooming Prairie Field.

While most of the company's property is in Divide County, it also drilled the 36-161-93H horizontal development well in an unnamed field in Burke County, N.D. It didn't report well results, but it completed the well in December 2008 in the Sanish from 9,224 to 14,590 ft.

It also has completed wells in the Three Forks Formation.

Its more recent completions were in Ambrose and Blooming Prairie fields in Divide County.

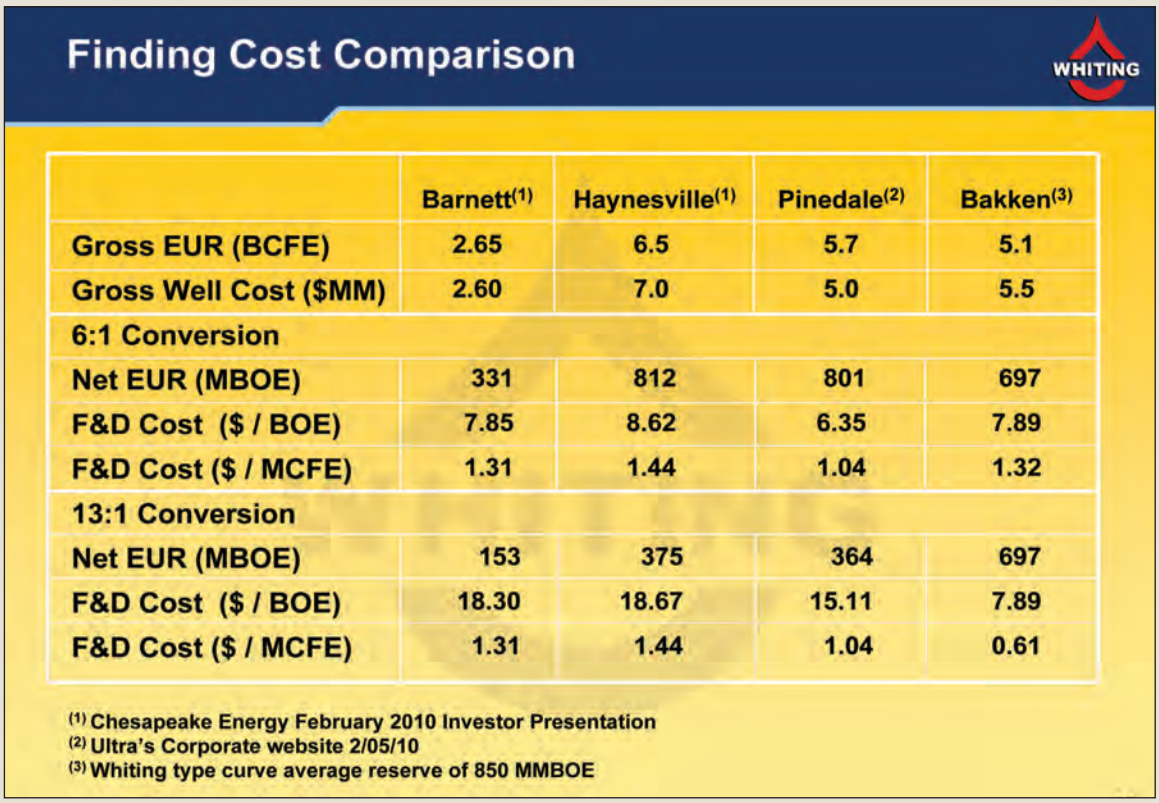
Saxon Oil Co. Ltd.

Saxon Oil Co. Ltd. had no Bakken or Three Forks production at the end of 2009, but the company had the property and had prospects.

Its North Dakota property included production from working interests in seven wells in Last Chance and Catwalk fields, and two more wells in Ambrose Field in North Dakota. At that point, the Madison Lime supplied all the production at Last Chance and Catwalk, and Duperow produced at Ambrose. Both fields are fully developed in those reservoirs, Saxon said.

"However, the deeper Bakken Shale has been completed in horizontal oil wells approximately two miles north of Saxon's leasehold at Last Chance and four miles south of Ambrose Field acreage. Bakken and Three Forks/Sanish drilling activity is anticipated on Saxon interest leasehold," the company said.

In a 2008 release, Saxon said it had approximately



	Barnett(1)	Haynesville(1)	Pinedale(2)	Bakken(3)
Gross EUR (BCFE)	2.65	6.5	5.7	5.1
Gross Well Cost ($MM)	2.60	7.0	5.0	5.5
6:1 Conversion				
Net EUR (MBOE)	331	812	801	697
F&D Cost ($ / BOE)	7.85	8.62	6.35	7.89
F&D Cost ($ / MCFE)	1.31	1.44	1.04	1.32
13:1 Conversion				
Net EUR (MBOE)	153	375	364	697
F&D Cost ($ / BOE)	18.30	18.67	15.11	7.89
F&D Cost ($ / MCFE)	1.31	1.44	1.04	0.61

(1) Chesapeake Energy February 2010 Investor Presentation
(2) Ultra's Corporate website 2/05/10
(3) Whiting type curve average reserve of 850 MMBOE

Information gathered from Chesapeake Energy and Ultra Petroleum helps to show Bakken potential and the reason it continues to pay off for operators in spite of lower production prices. *(Chart courtesy of Whiting Petroleum Corp.)*

1,800 gross acres with Bakken potential in North Dakota within six separate sections.

At that time, Whiting Petroleum Corp. operated its Ambrose Field properties in Divide County, and Saxon had interests from 7% to 17% in two Duperow wells. Samson Resources Co. had three horizontal Bakken wells in the field, but Saxon had no percentage in those wells, which were two miles southeast of its acreage.

Newfield Exploration Co. was operating Saxon's interest acreage in Catwalk Field in Williams County. Saxon had 7% to 27% working interests in four wells producing from the Madison Lime in that field. Tri-C Resources Inc. had drilled a horizontal Bakken well in the field, but not where Saxon had an interest.

Saxon had no proven or probable Bakken reserves at that time.

Sinclair Oil Corp.

Sinclair Oil Corp. operates Bakken properties in the Williston Basin through its Sinclair Oil & Gas Co. subsidiary.

It's not a big operator in the play, but it does make an impact. The company petitioned the North Dakota Industrial Commission in May 2008 for permission to conduct a simultaneous fracture treatment in two parallel horizontal wells in the same 1,280-acre spacing unit in Sanish Field in Mountrail County, N.D.

Results of that test weren't readily available, but that technique – which has been successful in the Barnett gas shale in North Texas – still is not being used widely in the North Dakota Bakken play.

Meanwhile, Sinclair continued a small drilling program. In 2008, it completed the Nelson 1-26H, drilled on a Northern Oil & Gas Co. farm-out in Mountrail County and completed for 750 b/d of oil.

It also had two Bakken wells in Richland County, Mont., that came in at initial potentials of more than 300 boe/d.

According to the *Rocky Mountain Oil Journal*, the company was the 23rd largest Bakken producer in 2008 with 111,295 bbl of oil from three wells.

In March 2010, it had the Patterson 167 rig drilling the Sinclair State 1-36H, and it had drilled the Highland 1-9H well on a Northern Oil & Gas farm-out in Mountrail County. That well tested for 56 b/d of oil.

Slawson Exploration Co.

Privately held Slawson Exploration Co. started operations in the Williston Basin more than 27 years ago, and it remains one of the most active companies in the basin.

For example, in September 2008, the company had 27 wells on the North Dakota Industrial Commission tight hole list. By March 2010, that number had grown to 40.

It has drilled in some of the hottest areas in the Bakken play, including Parshall and Ross fields in Mountrail County, many of the wells on land drilled under agreements with Northern Oil & Gas Co.; and it has drilled some of the better wells in the play, from the Pathfinder 1-9H in 2008 that offered initial production of 1,500 b/d of oil and from the Prowler 1-16H, in the same county, with an initial potential of 950 b/d of oil, both in 2008.

In November 2009, Slawson picked up 12,000 net acres in a North Dakota lease sale in the 50-50 agreement with Northern Oil & Gas. Northern also acquired 11,000 net acres in Slawson's Big Sky Bakken program in Richland County, Mont., and Northern added 13,000 net acres when it got a half interest in Slawson's Anvil properties in Williams County, N.D., and Roosevelt County, Mont.

Slawson drilled a Mountrail County well in February 2009 on Northern land that tested for 1,117 boe/d. Slawson was working five drilling rigs on land in Mountrail County that it acquired from Windsor Bakken LLC, and planned to drill 60 wells on the property in the 14 months starting in January 2010.

As the company drilled, results improved. Slawson's first wells in Mountrail County used nine fracture stages on 640-acre spacing. Later wells increased fracture treatments from 18 to 22, and resulted in 60% higher average production in the first 60 days online.

Slawson's Stallion 1-1-12H well – completed in February 2010 – used 36 frac stages in a 9,330-ft horizontal leg for an initial production rate of 2,735 boe/d and first-20-day average of 1,525 boe/d.

In addition, Slawson signed an agreement with Triangle Petroleum Corp. in February 2010 for the development of 4,000 net acres in Williams and McKenzie counties.

Triangle chief executive officer, Peter Hill, said, "Slawson is an ideal partner, and we are delighted to be associated with their entire team. They are experienced, have strong local content and knowledge, and are one of the lowest-cost, most-efficient operators in the business."

SM Energy Co.

SM Energy Co., the former St. Mary Land & Exploration Co., set its highest operating priorities on three resource plays, the Haynesville, Marcellus, and Eagle Ford shales, but it has additional action in its arena, including the Bakken Shale in North Dakota.

It also has strong operations in the Wolfcamp-Spraberry trend in the Permian Basin, the Granite Wash play in South Texas, the Woodford Shale in Oklahoma, and the Niobrara in the northern Denver-Julesburg Basin.

In the 4Q 2009 report to shareholders, SM Energy said it held 70,000 net acres in North Dakota that were prospective for the Bakken and Three Forks formations. That was 17,000 net acres more than it had at the end of 2008.

It held 48,000 net acres in McKenzie and Williams counties prospective for both formations, and another 21,000 acres in Divide County primarily prospective for the Three Forks Formation.

It planned to drill 17 operated wells in the Williston Basin in 2010, most of them in its Bear Den area in McKenzie County.

SM Energy also showed its willingness to try advanced technology with a test to determine the connectivity between the Bakken and Three Forks. It drilled two horizontal wells, one to the Bakken and the other to the Three Forks, and simultaneously fractured both wells for an initial potential of 2,800 boe/d.

Early in 2010, SM Energy planned to monitor the performance of the wells over a number of months to find out whether the combined production of the two wells will produce more reserves than single zone completions.

Simultaneous fractures of parallel wells have shown an incremental increase in reserves in gas shale plays, including the Barnett.

At the end of 2010, SM Energy was concentrating its operations on its core plays and on its secondary plays, including the Bakken. It divested some non-core properties in the Rocky Mountains, including some Williston Basin holdings and coalbed methane assets on the Montana-Wyoming border.

Stetson Oil & Gas Ltd.

Stetson Oil & Gas Ltd., with properties in North Dakota and Canada, began work in the Bakken play in North Dakota in July 2008 when it reached an agreement with the Three Affiliated Tribes on the Fort Berthold Indian Reservation for rights to 8,185 acres of tribal land.

The company acquired another 12,696 acres of freehold lands to raise its position to 20,881 acres.

Three months later it brought in Red Willow Great Plains LLC, the oil and gas production business of the Southern Ute Indian Tribe, as a partner to develop its Fort Berthold lands. Red Willow farmed in for a half interest in the freehold land and 60% of the tribal land, and agreed to pay the first US $3.5 million of Stetson's drilling costs on the properties.

Under the agreement, Stetson would operate wells on the freehold land and Red Willow would operate on tribal land as the companies worked their commitment to drill three initial wells.

Stetson started drilling the first joint well in August 2009 as operator with a 48.75% interest, and Red Willow applied for a permit to drill its first well five miles to the southeast at about the same time.

By February 2010, Stetson had installed a pumpjack on its MHA-1-11H-148-90 horizontal well and produced about 50 b/d of oil, and the companies were evaluating Bakken potential. By that time, it had produced 1,470 bbl of oil.

Stetson and Red Willow also agreed to acquire some 220 miles of existing 2-D seismic data to help locate high-potential drilling sites.

Summit Resources Inc.

Summit Resources Inc., the subsidiary of Paramount Petroleum Ltd. that works in North Dakota, is checking potential in Bakken through Birdbear zones on the company's 75,000 net acres around Medora in Billings County, N.D., on land with Bakken and Three Forks potential. The company entered the play along the fringe of the Upper Bakken in 2002.

In 2007, the company assigned two drilling rigs, the Paramount 1 and 2, to the program to develop more than 90 drilling locations. At that time, the company assumed a horizontal well would cost US $4.5 million and reach 300,000 boe in reserves with an initial potential of 200 b/d of oil. Since that time, it pulled one of the rigs back to Canada, but one remains at work in North Dakota. Paramount said lower commodity prices limited Summit's 2009 program to a single completion of a well it drilled in 3Q 2008.

Production had reached 1,000 boe/d in September 2008, and climbed to 1,200 boe/d by the end of 2010.

The *Rocky Mountain Oil Journal* named Summit the 26th most prolific producer in North Dakota in 2008, with production of 288,398 bbl of oil and 236.8 MMcf of gas from 37 wells, but all that production isn't necessarily from the Bakken zone. Summit produces from the Bakken, Birdbear, Mission Canyon, Duperow, Stonewall, and Red River formations.

According to a March 2010 Paramount presentation, a recent well by another operator near its leases came in at 1,900 boe/d and produced 22,000 boe in its first 40 days online. Summit is assessing the successes in the area by other operators to try to improve its own results.

In its year-end 2009 report to shareholders, Paramount said it spent approximately $7 million in its southern area in 2009, and most of that money went into the completion of a Bakken well in North Dakota.

For 2010, Paramount directed its entire exploration and production budget to its Canadian operations.

Sundance Energy Ltd.

Sundance Energy Ltd. of Australia is working the Bakken play in North Dakota through joint ventures with some of the more active operators in the Williston Basin. It planned to participate in more than 40 wells in North Dakota in 2010.

According to a March 2010 Sundance presentation, the company had interests ranging from 7% to 50% in its joint venture with Helis Oil & Gas Co. LLC. Helis drilled 10 wells in the South Antelope prospect area in McKenzie County, N.D. in 2008 with an average initial potential of 633 b/d of oil and 605 Mcf/d of gas, or 734 boe/d.

Sundance had 27,355 gross, or 4,176 net, acres in the area with 12 wells on production in early 2010, and Helis planned to drill eight gross (0.846 net to Sundance) wells in 2010 at a cost to Sundance of US $5 million.

Sundance also has a joint venture with EOG Resources Inc. as the operating partner. That's the Phoenix project, also in McKenzie County, where Sundance has a 10% interest. The venture has 9,605 gross (1,520 net to Sundance) acres.

In 2010, EOG planned 11 gross (0.675 net to Sundance) wells for a projected investment of $3.75 million plus a $1 million carried position. Phoenix has given the company a historic 43% rate of return.

The company also had a joint venture, with a 5% Sundance interest, in American Oil & Gas Inc.'s Goliath project in Williams County, N.D. That project covered 88,572 gross (3,299 net to Sundance) acres.

American planned 24 gross (0.59 net to Sundance) wells in 2010, with a projected Sundance capital expenditure of $3.5 million.

Sundance worked up the Bakken economics at Rough Rider and Ross fields. At a cost of $6.3 million/well, the four most recent wells showed an initial potential of 3,640 boe/d; 2,613 boe/d; 3,394 boe/d; and 3,807 boe/d.

Using 9,500-ft laterals with 20 to 32 frac stages in about 360-ft intervals and more fracture stages at smaller intervals seem to produce more oil.

It calculated a finding and development cost of $15.25/boe at an early 2009 Rough Rider well with a 9,500-ft lateral and 20 frac stages in 475-ft intervals. The well cost was $6.1 million with anticipated recoveries of 500,000 bbl.

It estimated a finding and development cost of $11.16/boe in a mid-2009 well at Ross. That well also had a 9,500-ft lateral, but it had 24 frac stages in 400-ft intervals. The well cost grew to $6.25 million, but the estimated recovery grew to 700,000 boe.

At $80/bbl oil and $4.50/Mcf gas, it expected a $6 million well to give the company a 55% internal rate of return, using a net present value discount of 10%.

Tracker Resource Development II LLC

Tracker Resource Development II LLC has an active program in the works to prove up its portion of the Bakken play in North Dakota.

The company held 84,000 net acres in the Middle Bakken play in early 2010 on leases with more than 300 MMbbl of oil in place. Those assets are held in joint venture with TRZ Energy, LLC. Tracker is the operator.

The company had drilled 21 wells in the Bakken or Three Forks formations by September 2009.

That was a considerable improvement from its position nine months earlier. According to the *Rocky Mountain Oil Journal*, Tracker was the 19th most prolific operator in the Bakken play in North Dakota in 2008, with production of 148,493 bbl of oil from 10 wells.

A substantial amount of its property is in Dunn County where Tracker asked the North Dakota Industrial Commission to add 80 sections to Little Knife Field in July 2008. The commission reduced that number to about 68 and approved the request.

Tracker remained active into the oil and gas price downturn. In December 2009, the Bakkenstocks.com Web site said the company was using the Nabors

182 rig to drill the Larsen 13-1H well and the Nabors 44 rig to drill the Danielle 12-1H.

Triangle Petroleum Corp.

Triangle Petroleum Corp. is brand new to the Bakken play in North Dakota, but the company has ambitious plans and an experienced partner to give it a boost toward success.

Triangle also has an 87% interest in some 474,000 gross acres in Nova Scotia's Maritimes Basin.

In February 2010, the company announced that it had a "new strategic initiative" in the Bakken when it acquired 4,000 net acres of land in Williams and McKenzie counties.

At the same time, it said it formed a partnership with Slawson Exploration Co., one of the more active and successful Bakken drillers. The partnership would acquire more land and develop it in known areas of production from the Bakken and Three Forks. That partnership would last for two years.

In a presentation in the same month, the company added that the 4,000 net acres contain seven drilling locations, and it had a 30% working interest in the properties. Under the agreement, Triangle will pay a third of the well cost to earn a 30% interest in all wells drilled in the area of mutual interest.

Eighteen months into the future, the company said it wanted to accumulate 100,000 gross, 30,000 net, acres in the play, including 10,000 net acres by the end of 2010.

Triangle estimated finding and development costs at US $12/bbl of oil and a drilling and completion cost of $6 million to find 500,000 bbl of oil.

The partners planned to begin drilling their first well in 3Q 2010. That well will be in the Rough Rider area, which has proven flush production. Slawson will operate all the wells.

The partnership agreement called for gross capital expenditures of $24 million a year, with both companies holding an option to drop out of the agreement at any time.

Ursa Resources LLC

Privately held Ursa Resources LLC focused its attention on the Bakken play in the Williston during 2010, and is assembling land and prospects to begin an active campaign in the popular play.

When it formed in 2008, the company looked to

acquisition, exploration, development, and production of energy onshore in the US as its path to growth.

It set up a relationship with a Houston investment company in March 2009, and began acquiring producing properties, and by February 2010, it had shifted exclusively to the Bakken.

"We have studied the Williston Basin for years and are eager to apply our team of shale play experts' skills to the challenges presented by the Bakken. Being born and raised in Sidney, Mont., the opportunity to go back and work with the local people to develop their resources makes it even more exciting for me," said Bruce Larsen, executive vice president.

The company agreed to acquire more than 500 net acres of prospective Bakken land in McKenzie County, N.D., with an option to add up to 2,000 additional acres.

In February 2010, Ursa added another 1,700 net acres in the county, and was trying to accumulate additional properties with an emphasis on McKenzie County in North Dakota and Richland County in Montana.

US Energy Corp.

US Energy Corp. set a goal to produce 2,000 boe/d by the middle of 2010 and 2,500 boe/d by the end of the year – up from 1,400 boe/d at the end of 2009 – with a big push from the Bakken Formation in North Dakota.

The company is on track to reach its goal, and possibly exceed it, thanks to a hookup with the right operator in the right area of the play.

US Energy signed a participation agreement with Brigham Exploration Co. on Aug. 26, 2009, according to a February 2010 US Energy presentation. Under that agreement, US Energy signed up to participate in 15 wells on 1,280-acres spacing. Participation in the full program will give US Energy about 5,500 net acres in Brigham's Rough Rider Field on the border of Williams and McKenzie counties.

Brigham had drilled the first six wells by Jan. 5, 2010, and planned to complete the program by the end of June using up to three drilling rigs. US Energy anticipated investing US $17.6 million on those first six wells.

Initial potential (IP) results by February included:

- Brad Olson, IP 2,112 boe/d, 61% working interest (WI), 48% net revenue interest (NRI);
- BCD Farms, IP 1,776 boe/d, 45% WI, 35.55% NRI;
- Lee, IP 1,544 boe/d, 60% WI, 47% NRI;
- Strand, IP 2,264 boe/d, 40% WI, 31% NRI;
- Williston, IP 3,394 boe/d, 65% WI, 51% NRI; and
- State, IP 3,807 boe/d, 29% WI, 23% NRI.

Since each of the 1,280-acre spacing units are capable of supporting three Bakken wells and three Three Forks wells, the mutual-interest acreage has potential to support up to 90 total wells. Brigham will operate all of the wells.

In March 2010, US Energy said Brigham completed the Papineau Trust 17-70 #1H for 2,616 b/d of oil and 2.55 MMcf/d of gas, or 3,042 boe/d, and the Kalil 25-36 #1H for 1,334 b/d of oil and 1.51 MMcf/d of gas, or 1,586 boe/d, after a 30-stage frac treatment.

The company also completed the Jack Erickson 6-31 #1H well to approximately 20,000 ft measured depth in April for 2,323 b/d of oil and 1.98 MMcf/d of gas.

Brigham started drilling the 10th well in the series, the Sedlacek Trust 33-4 #1 H, on March 8, 2010.

Viper Resources Inc.

Viper Resources Inc., the previous Cobra Oil & Gas Co., has an option to acquire a half interest, with a 100% working interest and an 80% net revenue interest in 82,000 acres of land on the Montana side of the Williston Basin.

The company's potential property holding lies in Valley County, one county west of the main Bakken production in Montana's Elm Coulee Field. Elm Coulee had more than 350 producing wells with an ultimate estimated production target of 270 MMbbl of oil in 2006, Viper said.

The Viper properties are on trend with multiple shallow gas trends, primarily the Judith River and Eagle, and multiple deeper oil trends, including the Mission Canyon, Lodgepole, and Bakken, the company said. The company estimated 260 Bcf of gas reserves on the property.

Viper hasn't yet generated any operating revenues on its Montana properties or on its heavy oil sands property in Utah.

Whiting Petroleum Corp.

Whiting Petroleum Corp. easily qualified as one of the top operators in the Bakken/Three Forks play as the North Dakota Industrial Commission ranked it fourth in production for all formations in the state at 6.76 MMboe in 2009.

In a March 2010 presentation, Whiting said it had three main areas of interest in North Dakota's Sanish Field, where it is the operator of its wells with a development program; Lewis & Clark Field in southwestern North Dakota, where it is exploring the Three Forks; and Parshall Field, where it participates as a non-operator.

At the end of 2009, it had proved and probable reserves

of 63 MMboe at Sanish and 9 MMboe at Parshall.

The company's resource potential, assuming US $75/bbl oil and $6/Mcf gas, is much higher.

Lewis & Clark had a potential of 57.57 MMbbl of oil, 4.86 MMbbl of NGLs, and 23.89 Bcf of gas for a total 66.41 MMboe.

If the company increased Three Forks density to three wells per 1,280-acres unit from two wells, Sanish Field had the potential to produce 13.89 MMbbl of oil, 1.87 MMbbl of NGLs, and 7.3 Bcf of gas for a total of 16.97 MMboe, in addition to existing reserves.

Since the company drilled its first Sanish Field well in 2006, it has completed more than 130 producers and set North Dakota records with initial potentials of 4,761 boe/d at the Maki 11-26H and 4,570 boe/d at the Richardson Federal 11-9H, its top two wells. It planned 253 Bakken wells and 140 Three Forks wells in that field.

Whiting anticipated running nine rigs at Sanish through 2012.

To realize that potential, Whiting planned to spend $981 million at Lewis & Clark, $234 million at Sanish, and $165 million on its other Williston Basin properties.

Whiting planned to spend $274 million at Sanish in 2010 to drill 86 gross, 48 net, wells; $62 million at Lewis & Clark to drill 13 gross, nine net, wells; and $11 million at Parshall to drill 12 gross, two net, wells.

Whiting had additional Three Forks and Red River potential in the Williston Basin totaling 12.14 MMboe of possible additional production.

Overall, Whiting held 192,889 gross, 88,048 net, acres of land in Sanish and Parshall where the average estimated ultimate recoveries were 850,000 boe/well, and wells cost $5.5 million to completion.

It drilled 38 wells in Sanish Field in 2009 with an average 61% working interest. Whiting drilled 66 operated wells in the field between Jan. 1, 2008 and Feb. 15, 2010. Those wells had an initial average production rate of 2,093 boe/d.

Lewis & Clark had 250 1,280-acre units, or room for 500 wells at two wells per unit.

Among the non-operated Parshall wells, Whiting held an average 20% working interest.

Among all the wells, the company drilled to the Bakken and Three Forks in 2008, 2009, and 2010, the average initial potential was 2,093 boe/d, the 30-day average was 858 boe/d, and the 60-day average was 713 boe/d.

Outlining the economics of the play, Whiting said wells with 950,000 boe of ultimate recovery and a capital expenditure of $5.5 million offered a 6.2% return on investment and a 233% internal rate of return at a New York Mercantile Exchange oil price of $70/bbl.

If the well recovered only 750,000 boe, the return on investment still reached 4.9%, and the internal rate of return was 198%. Those were figures for east and central Sanish Field. Returns from the western part of the field were lower.

Whiting works on technology to improve well efficiency.

In October 2009, Baker Hughes said it ran a 24-stage completion for Whiting, one of the largest numbers of stages ever run with a ball and sleeve isolation system. Most operators use expandable packers to isolate zones for fracturing and later drill out the packers for production.

The Baker Oil Tools completion used its FracPoint EX multistage system on Whiting's Ogden 11-3H well for a single-trip isolation of the intervals with an 8,000 psi pressure rating while achieving high fracture rates through all the ball seats. According to Baker Oil Tools president, Bob Bennett, the tool lowers operating costs and increases completion performance for operators.

Rick Ross, Whiting vice president of operations, added, "As our ability to efficiently drill and complete longer horizontal laterals has increased, the need to increase the number of frac stages that can be pumped with a ball/sleeve system has become critically important to Whiting."

Windsor Bakken LLC

Windsor Bakken LLC, an affiliate of the Windsor Energy Group, started collecting land and investors early in the Bakken play, and drilled its first well in September 2007.

By that time, it held 64,100 net acres in land prospective for the Bakken and had bids out for another 45,700 acres. Much of that land lay in prime Bakken territory in Parshall Field in Mountrail County.

By the end of 2008, North Dakota called Windsor Energy Group the 17th most prolific producer in the Bakken, with output of 211,142 bbl of oil from two wells.

In June 2009, Windsor Bakken made a couple of important sales. In one sale, Northern Oil & Gas Co. entered into an exploration and development agreement with Slawson Exploration Co. in which Northern bought certain Windsor Bakken assets as part of a syndicate led

by Slawson. The US $7.3-million purchase gave Northern a 5% interest in undeveloped acreage, including some 60,000 net acres. It also got 14% of the company's 59 gross Bakken and Three Forks wells in North Dakota, and some 1,200 b/d of production from those wells.

In the same month, GeoResources Inc. and Slawson, as joint venture partners, acquired another interest, apparently in the same package for $10.4 million. Northern and Lario Oil & Gas Co. were participants. GeoResources got a 15% interest in 60,000 net acres, 15% of varying working interests in the 59 wells, and net proved producing reserves of 300,000 boe. Net daily production was 180 b/d of oil.

Northern said Slawson, the operator, started developing the Windsor properties with a five-rig drilling program and anticipated drilling 60 gross wells in the following 14 months.

By that time, 17 of the 60 wells had been completed.

The first well in the program, the Genesis 1-13H, reached total depth with a 5,000-ft lateral in 16 days, at a cost of $2.9 million after an 18-stage frac treatment. It gave the companies initial output of 2,589 boe/d on a 3⁄4-in. choke.

Windsor apparently didn't sell all of its Bakken interests. The company's Internet site still lists Windsor Bakken as an affiliate and the Williston Basin as one of its focus areas.

XTO Energy Inc.

No wonder Exxon Mobil Corp. wanted to buy XTO Energy Inc. and set it up as its gas and oil shale center of expertise – it has the expertise ExxonMobil needs to solidify its fast-growing international unconventional resource empire.

XTO is one of the nation's largest independent companies and a major unconventional resource operator in the US, an attribute that made it worth a US $41-billion-bid, including $10 billion in debt, from the world's largest public energy company.

XTO held 280,000 net acres in the Marcellus Shale, 380,000 net acres in the Fayetteville, 100,000 acres in the Haynesville, 160,000 acres in the Woodford, 275,000 acres in the Barnett Shale, tight sand properties in East Texas and Utah, and coalbed methane in the San Juan and Raton basins.

The company's largest single-shale holding, at 450,000 acres, is in the Bakken oil shale play.

That would fit nicely with ExxonMobil's existing unconventional resource properties in the Marcellus, the Haynesville, the Piceance Basin, the Horn River Shale of Canada, and unconventional resources in Germany, Poland, Hungary, and Argentina.

In all, ExxonMobil had more than five million net acres in gas shale plays, and 60% of those holdings were outside the US at the time of the company's takeover bid for XTO.

XTO jumped into a leading position in the Bakken in July 2008 when it bought Headington Oil Co. for $1.8 billion in cash and stock. That gave the company 352,000 net acres in the Bakken, including a major position in Elm Coulee Field in Montana.

At the time, XTO estimated proved reserves on the Headington properties at 68 MMboe, and 60% of those reserves were in the proved developed category. It also got some 10,000 b/d of oil production.

In September 2008, the company bought Hunt Petroleum Corp. for $4.2 billion in cash and stock to add another 100,000 acres of Bakken leases and 400 b/d of oil production from the Bakken.

At that time, XTO had three rigs at work in the play, and planned to double that number in the first half of 2009. It was getting 650 b/d from its Bakken wells and was planning its first Three Forks/Sanish horizontal well.

In a 3Q 2009 presentation, XTO said it had three rigs at work in the Bakken and produced 13,800 boe/d – up 15% from the previous quarter and 40% higher than the middle of 2008.

Its wells came in at considerably higher rates. It completed the Federal 34x-14 in the Bakken for 1,880 boe/d. It also completed four high-rate Three Forks/Sanish wells: the Jorgenson 43x-5 for 1,660 boe/d, the Jorgenson 43x-4 for 2,825 boe/d, the Marmon 41x-12 for 1,345 boe/d, and the Jorgenson 41x-6 for 1,185 boe/d.

Since those earlier wells, XTO has followed the industry trend with longer laterals, more completion stages, and frac treatments at closer intervals. Later wells used 10- to 12-stage completions.

XTO also is evaluating variations of super pads for development work in the Bakken and Three Forks/Sanish. Under that concept it would drill multiple horizontal wells from a single pad to save site construction costs and rig movement costs and take up a smaller environmental footprint for its drilling program.

The company has drilled some of the stronger wells brought in to date from the Three Forks/Sanish Formation. XTO's holdings in North Dakota are generally south of the Nesson Anticline, and the strongest Bakken pro-

duction has come from Parshall and Ross fields east of the Nesson Anticline.

In early 2010, only 27% of the company's Bakken-prone leases are in Elm Coulee Field in Montana, which accounted for three-quarters of its Headington purchase.

Now, it's working properties on that field with an infill program on 640-acres spacing.

During late 2009, XTO was drilling with three rigs in its Bakken activity, but it expected to raise that count to six rigs in 2010.

Zenergy Inc.

Zenergy Inc. and its Zenergy Operating Co. LLC affiliate were aggressive drillers in the Bakken/Three Forks play in North Dakota early in 2010. Zenergy is the former Zinke & Trumbo, Inc. of Tulsa.

In May 2010, the companies had 23 wells on the North Dakota Industrial Commission confidential list. Most were in Zenergy Operating Co.'s Dakota-3 series of wells in Dunn County, while Zenergy was drilling in McKenzie County.

In late January 2010, the companies had four rigs working, and it still had three rigs making hole in late February.

An April 2010 article in the *Minot Daily News* (North Dakota) said Zenergy was one of the companies working on the Fort Berthold Three Affiliated Tribes Reservation in North Dakota.

Earthstone Energy Inc. said its Pederson #10-3H well in Banks Field, in eastern McKenzie County, was operated by Zenergy. Earthstone held a 2.4% working interest in that well. Zenergy had filed for multiple drilling permits in the area.

Anterra Energy Inc.

Canada Key Players

Calgary, Alberta, Canada-based Anterra Energy Inc. worked several plays in southern Canada early in 2010, and the company gained a foothold in the Bakken Shale play in southeastern Saskatchewan.

In May 2010, the company said it acquired 7,526 net acres of Crown Point Ventures Ltd. land in Saskatchewan to raise its Bakken- and Mississippian-prospective holdings to 10,880 net acres, or 17 sections. At that time, it had spent US $563,112 (Cdn $600,000) on its Bakken prospect.

Although it had no active drilling program at the time, it planned a 3-D seismic program over the territory during the summer of 2010, and if results were promising, would drill its first Bakken well in late 2010 or early 2011, according to its 2009 report to shareholders.

Crescent Point Energy Corp.

Crescent Point Energy Corp. of Calgary is the dominant player with a controlling position in Viewfield Field in southeastern Saskatchewan. The Bakken pool is the second largest conventional light oil pool discovered in western Canada and the largest conventional pool discovered in more than 50 years in western Canada.

The Bakken pool at Viewfield held an estimated 4.6 Bboe, and to date, only 0.6% of the hydrocarbons have been recovered. Crescent Point estimated it can recover 15% of the original oil in place with four wells per section, and detailed simulations suggest a 19% recovery is possible with eight wells per section.

If that 19% rate is borne out, Crescent Point would have 219 MMbbl of proved and probable reserves, more than double its current total.

In a January 2010 presentation, the company said its current production was 27,500 boe/d from 800 net sections, or 512,000 net acres of land. It had an inventory of 2,850 net drilling locations and a 110-well frac treatment inventory.

For 2010, Crescent Point set aside, US $194.8 million (Cdn $201 million) to drill 124 net Bakken wells and another $63 million ($65 million) for Bakken facilities at Viewfield.

By the end of 2008, the company had drilled 489 gross, 401 net, Bakken wells in the field and used advanced multistage stimulation techniques to raise post-stimulation production rates to more than 200 boe/d per well.

Crescent Point, an energy trust, gained its controlling interest in the field in 2007 with the acquisition of Mission Oil & Gas Inc. The field offered some of the highest netbacks in the industry and more than six years of low-risk development drilling inventory.

Later that year, the trust acquired Innova Exploration Ltd. to get another 4,300 boe/d of production, and 65% of that was from Viewfield Bakken wells. That acquisition added another 97 sections of undeveloped land and 380 net development locations to the trust's inventory.

In January 2008, Crescent Point acquired Pilot Energy Ltd. At that time, Pilot was producing approximately 1,000 boe/d, and half of that total came from the View-

field Bakken play. That increased Crescent Point's Bakken production to more than 12,500 boe/d.

At the same time, Crescent Point invested in a 20% interest in Shelter Bay Energy Ltd. and gave Shelter Bay access to Crescent Point's expertise to further consolidate the Canadian Bakken play.

By June 2008, the company said, the trust increased its dividend by 15% because of its success in the Bakken play and better than expected results from its core plays. Commodity prices had climbed at the same time.

Crescent Point raised its Bakken exposure again in December 2008 with the acquisition of Villanova Energy Corp. Villanova was producing 1,750 boe/d at the time, and 95% of that production came from Bakken properties adjacent to Crescent Point's producing area.

In the same month, it acquired 17% of Wild River Resources Ltd. with assets in the Bakken play.

The acquisition campaign continued into 2009 in spite of lower oil prices. In 1Q 2009, Crescent Point and TriStar Oil and Gas Ltd. jointly acquired all of Talisman Energy Inc. assets in southeastern Saskatchewan and Montana, including Talisman's Bakken properties.

Crescent Point got 4,000 boe/d of production out of the deal, with 700 boe/d of that total coming from the Bakken.

In March, the company acquired the remainder of Wild River Resources Ltd. and Gibraltar Exploration Ltd. to gain another 110 net sections of undeveloped land and 85 net drilling locations, along with 2,900 boe/d of production.

Crescent Point converted from a trust to a corporation in July 2009, but paid the same dividend to shareholders as it did when it was a trust.

In November 2009, Crescent Point acquired TriAxon Resources Ltd. in a stock trade. TriAxon had Bakken and Viking light oil assets in Saskatchewan and additional interests in the Pembina Cardium play in Alberta.

TriAxon also had more than 148 net sections of undeveloped land, and it operated the Flat Lake Bakken play, in which Crescent Point previously held a working interest. TriAxon was producing 1,400 boe/d, but only 170 boe/d came from Flat Lake.

Following that acquisition, Crescent Point signed a joint venture agreement with Ryland Oil Corp., which previously had a joint venture agreement with TriAxon at Flat Lake. Crescent Point took over as operator of the venture and its third farm-in horizontal well on Ryland's property produced 180 b/d of oil. In that arrangement, Crescent Point paid 100% of the drilling, completion, and equipment costs to earn a half interest in the well.

Crescent Point could earn rights throughout Ryland's Flat Lake acreage by drilling seven earning wells.

Crown Point Ventures Ltd.

Vancouver, Canada-based Crown Point Ventures Ltd. holds Bakken Formation properties in Saskatchewan and Manitoba with wells drilled by operating partners.

In southeastern Saskatchewan, the company worked with Interwest Enterprises Ltd. In June 2009, the companies planned to drill and complete a Bakken well in their area of mutual interest with Crown Point holding a 47.5% interest. The new well offset a well in which the company participated in 2008.

At the same time, the company's Manitoba partner, Tundra Oil & Gas, told Crown Point it planned to drill one to three horizontal Bakken wells in the summer of 2009 in the Daly Field. Crown Point had a 25% working interest in the first of those wells.

The two companies spudded an earlier well in the field in February 2009.

Crown Point announced two discoveries in Saskatchewan in September 2008, but the wells were held on confidential status by the operator. Crown Point said, "Based on the success of the initial two-well drill program, the company, along with its partners, have been able to secure the hydrocarbon rights to an additional 640 acres of land encompassing the Bakken play in the same area of southeastern Saskatchewan."

The additional land raised the partners' gross acreage in the area to 6,640 acres, 5,640 net. The land is in the Wapella area.

Enerplus Resources Fund

Enerplus Resources Fund, Canada's oldest and second largest energy income trust, entered the Bakken play in the US when it bought the Montana Elm Coulee Field properties of Bakken pioneer Lyco Energy Corp. Elm Coulee has produced more than 70 MMboe.

That acquisition, which Lyco had consolidated into its Sleeping Giant project in Richland County, sold for US $421 million (Cdn $509 million), and it formed the base for Enerplus Bakken operations in Montana,

North Dakota, and Saskatchewan.

In early 2010, Enerplus was moving from a strictly income organization to an income and growth orientation, and its Bakken properties formed one of the rungs on that growth ladder.

In its report on 2009 activities, the fund said it had accumulated some 100 net sections, or 64,000 acres, of undeveloped Bakken land in Canada and the US. That included a one-fourth working interest in 44 gross sections in southeastern Saskatchewan, and a half interest in some 34 gross sections of prospective Bakken land in North Dakota.

It spent $47.6 million ($49 million) on its Bakken properties in 2009 and ended the year with production of 10,075 boe/d – up 1,782 boe/d from its 2008 average.

It drilled 6.2 net horizontal wells during the year and brought 1.5 of them online. The other 4.7 net wells were awaiting completion or hookup to sales. That work was concentrated on the Sleeping Giant properties and assessment of new properties.

At the end of 2009, it had 32 MMboe in proved reserves and 9.7 MMboe in probable reserves in its Bakken properties.

As production declined, the company finished 2009 with 8,750 boe/d in Bakken production, but it planned to spend $114.5 million ($118 million) to drill 42 net wells in 2010. It expected that program to give it an average Bakken production of 11,200 boe/d for all of 2010, with an exit production rate of 12,200 boe/d. That compared with production of 7,000 boe/d when the company bought its original Bakken properties in 2005.

It also planned to increase the number of fracture stages on new wells at Sleeping Giant, using up to 12 frac stages.

Epsilon Energy Ltd.

Epsilon Energy Ltd., widely known for its position in the Marcellus Shale play in Appalachia in which Chesapeake Energy Corp. farmed in to carry the company in a drilling program, also held a stake in the Bakken oil play in southeastern Saskatchewan.

The company held 17,640 net acres in Saskatchewan, according to a May 2010 presentation. That was part of 39,000 gross acres within a 63,360-acre area of mutual interest with Spartan Energy as operator. The first well drilled in the combination produced at a rate of 15 b/d of oil.

Called the Bakken Torquay prospect, the area of mutual interest included 7,680 gross, 3,840 net, acres, in which Epsilon held a half interest. The area contained more than 20 potential drilling locations. It also included 31,385 gross, 13,800 net, acres, also with Spartan as operator, in which Epsilon held a 44% share in more than 80 potential locations.

Under the agreement, Epsilon was required to carry Spartan's costs on two mandatory wells and two optional wells to earn its half interest in the smaller property. The companies planned a 3-D seismic survey in the area of mutual interest.

Madison Energy Corp.

Madison Energy Corp. drilled its first successful well in Garrington, Alberta, Canada, in November 2004, and it's been working the Canadian oilpatch since that time, with four prime exploration and development areas.

One of those areas is the Bakken/Torquay light oil field on the border between Saskatchewan and Manitoba. The company held interests in 6.25 sections, or 920 acres, in the field, and it used horizontal wells with multiple fracture treatments to recover the oil. It held varying interests in wells in the field.

It acquired those properties late in 2008 and participated in its first well in December of that year. Under the terms of the agreement, the company had a 45% working interest in the well before payout and a 35% interest after payout. It drilled to a true vertical depth of 3,281 ft and planned a 1,969-ft horizontal leg.

Bakken/Torquay in the Antler-Sinclair area hosted more than 500 vertical wells – the most drilled in the previous five years – and more than 60 horizontal wells – the most drilled or permitted in the previous two years.

Mogul Energy International Ltd.

Mogul Energy International Ltd. accumulated properties in California, Egypt, and in the Bakken play in southeastern Saskatchewan.

Its 100%-owned Fairlight area was near two shallow Bakken wells, both uneconomic, but the area also was prospective for Sourice Valley Mississippian-Lodgepole carbonates. Both the Lodgepole and the Bakken produce in North Dakota and Montana and in other parts of southeast Saskatchewan. The only production nearby came from four Chevron Corp. wells that produced from the Birdbear Formation.

Still, Mogul acquired some 9,300 acres and planned to

test the Birdbear, Lodgepole, and Bakken. Each of the shallow formations had the potential to produce between 25 and 100 b/d of oil, the company said, with potential recoverable reserves of 400,000 bbl of oil or more.

By December 2008, the company had started a three-well drilling program on the properties. The first well reached a heavily oil-stained marginal Bakken reservoir, and was suspended pending evaluation and land development.

It abandoned the second well when it found the Bakken reservoir wet. It planned to complete the final well in the series in January 2009, but it didn't report any operations results on its Web site after that time.

Painted Pony Petroleum Ltd.

Painted Pony Petroleum Ltd. was one of the more aggressive companies on the Canadian side of the Bakken oil play when it went public on May 23, 2007, and it has continued to gallop down that trail since that time.

By September 2008, it had drilled 11 gross, 3.74 net, wells on its way to a 40-well goal in 2008 on its 100 Bakken drilling locations. At the end of June that year, it had 53,000 acres of option land in southeastern Saskatchewan and added another 7,100 acres in August.

The Saskatchewan government spurred exploration and development at that time, with a horizontal well royalty incentive of a 2.5% royalty rate on the first 37,000 bbl of oil on Crown Point Ventures Ltd. land and a freehold mineral tax holiday on the first 37,000 bbl.

In addition, deep wells below 5,578 ft total vertical depth also got an incentive of a 2.5% royalty rate on Crown land and no freehold mineral tax on the first 106,000 bbl of oil. Those incentives remained in place in early 2010.

In a March 2010 presentation, the company said it continued its focus on light, sweet Bakken crude, but it had accumulated 59,800 net acres (97% undeveloped) by Jan. 31, 2010.

It had drilled another 19 gross, 16.5 net, Bakken wells in 2009 and drilled 10 more, 9.3 net, in 1Q 2010. Its wells were 95% operated.

In 4Q 2009, it sold 1,456 boe/d (98% oil) from its Saskatchewan properties with a netback of US $50.16 (Cdn $51) at a sales price of $69.81 ($71).

Among its Bakken properties, Painted Pony held 10,100 net acres in the Midale/Huntoon area after buying out its partner's interest in 3Q 2009. It drilled 16 gross, 15.7 net, wells in that area in 2009 and seven net wells in 1Q 2010. During 4Q 2009, it also built a gathering system and central tank battery.

It planned to keep two drilling rigs working in the Midale/Huntoon area throughout 2010.

In the Weyburn area, the company held 17,800 net acres. It drilled two gross, 1.3 net, wells in 1Q 2010.

Painted Pony allocated $88.49 million ($90 million) for all capital expenditures in 2010 and approximately 75% of the drilling, completion, and equipment segment of that budget will go to light oil operations, primarily the Bakken.

PetroBakken Energy Ltd.

PetroBakken Energy Ltd., one of the leading Bakken operators in Canada, generates higher reserves and returns by applying techniques not generally used by other operations.

Conventional wisdom in the US and Canada calls for multistage fracture treatments on long, single-lateral horizontal wells.

The company – which is the 64% affiliate of PetroBank Energy & Resources Ltd. that controls that company's Bakken properties in southeast Saskatchewan – has plenty of experience in the Bakken and with horizontal wells. It has more than 210,000 net undeveloped acres in the play with more than 1,100 potential drilling locations. It has booked only 342 proved and probable locations and has gathering, processing, and pipeline facilities in its producing area in southeastern Saskatchewan.

Much of the company's properties came from its 2009 acquisition of TriStar Oil and Gas Ltd. In 2Q 2008, that company had 797 gross, 531 net, drilling locations.

Earlier in 2009, TriStar had acquired half the Bakken properties of Talisman Energy Inc. in southeast Saskatchewan.

During 4Q 2009, PetroBakken drilled 64.8 net wells, for a total of 117.3 net wells for all of 2009. Most of those wells were in southeastern Saskatchewan where the company has both Bakken and conventional production.

In a March 2010 presentation, PetroBakken offered insight into the technology that gave it superior reserves. It has pioneered in the use of long, bilateral wells in the Bakken. At that time, it had drilled 65 long, bilateral wells, and had 50 of them on production.

To test results, it drilled bilateral wells in areas where it already had single-lateral wells. In one area, the bilateral tests outperformed single-lateral wells by 21%. In the

other area, the bilaterals won the competition by 52%.

In a comparison of 51 long, bilateral wells with 139 long, single-lateral wells, reserves from the bilaterals doubled reserves from the single laterals.

The company also increased reserves and production by increasing the number of stages it used in fracture treatments.

According to the company's Web site, apparently written before it started its bilateral program in July 2009, "Beginning in late 2006, we focused on deploying technologies to improve production rates and enhance recoveries. Through the use of an existing fracture stimulation technology, but modifying its application, we achieved production results that exceeded expectations by a wide margin. This approach involved eight-stage sequential fracturing in isolated high quality portions of the reservoir and allowed improved concentration and containment of the frac within the formation. We have since furthered the technology and were the first company to complete 20-stage fracs in a long horizontal well. Future plans include drilling long, bilateral wells, incorporating up to 20-stage fracs in both legs, which should provide maximum exposure to the Bakken reservoir."

Going into 2010, PetroBakken had 12 rigs drilling in southeast Saskatchewan, and 10 of them were drilling to the Bakken.

Ryland Oil Corp.

Ryland Oil Corp. built its position with Bakken production potential in southeastern Saskatchewan and in Montana and North Dakota starting with its acquisition of Pebble Petroleum Inc. and its leases in Saskatchewan in 2007.

It still operates those leases through its Pebble subsidiary. It operates its properties in the US through Rover Resources Inc.

In 2008, it increased its Bakken holdings with the purchase of Viceroy Resources Ltd., a company with a half interest in 4,320 acres of land in southeastern Saskatchewan and five producing wells. Two of the wells produced from the Bakken Formation at a combined rate of 15 b/d of oil. That land was adjacent to Ryland's properties.

In all, Ryland holds more than 300,000 acres of properties in Saskatchewan and the western US. That acreage includes 20,647 gross, 12,184 net, acres in the northwestern US.

In a January 2010 release, Ryland said it continues to focus on Bakken exploration on its 81 sections of land in the Flat Lake area of southeastern Saskatchewan where it is a joint venture partner with Crescent Point Energy Corp. Crescent Point is the operator and can earn a half interest in a portion of Ryland's acreage by providing 100% of the drilling, completion, and equipment costs.

That joint venture agreement originally involved Ryland and TriAxon Resources Ltd., but Crescent Point bought TriAxon and its share of the venture.

In January, Crescent Point completed a well in 1-22-1-14W2, the third earning farm-in well on Ryland land. That well produced approximately 180 b/d of oil.

Crescent Point also drilled and completed the fourth well at 3C5-30/4D8-30-1-1-15w2, some four miles northeast of the third well in the series. It completed the newer well with a 16-stage fracture treatment. It also completed the fifth earning well at 4C 14-12/4C14-13-1-15w2, about five miles west of the third well. Both wells were being equipped for production.

If Crescent Point completes a seventh well, it can earn a position throughout Ryland's Saskatchewan acreage.

Dick Findley, Ryland chairman, was credited with the initiation of Bakken recovery in Elm Coulee Field in northeastern Montana – the play that set off the current round of Bakken/Three Forks/Sanish exploration in Montana and North Dakota – and with revival of the play in Saskatchewan and Manitoba. In recognition of his work, Findley was named Outstanding Explorer of the Year by the American Association of Petroleum Geologists in 2006.

Tom Lantern, vice president, engineering for Ryland, oversaw the initial development of Elm Coulee Field when he worked for Halliburton Energy Services as an asset manager, the company said.

Shelter Bay Energy Ltd.

Shelter Bay Energy Ltd. is a closely held company that started operations in January 2008 to explore and develop Bakken properties in southeastern Saskatchewan.

The company was organized by Crescent Point Energy Trust – the biggest overall producer and the biggest Bakken producer in the area – and it wanted Shelter Bay to handle exploration and development work in its portion of the 1,000-sq mile Viewfield area in southeastern Saskatchewan where experts estimate some 4 Bbbl of Bakken oil in place. Crescent Point already had more than 260 net Bakken wells in the area.

Although Crescent Point helped organize and fund the

company, and provides Shelter Bay's top executives, it doesn't exert tight control over the company.

Scott Saxberg, chief executive officer and a director of Shelter Bay, also is president, chief executive officer, and a director of Crescent Point.

Crescent Point also farmed out 22 sections of its undeveloped Bakken holdings to Shelter Bay and invested US $52.46 million (Cdn $56.1 million) for a 20% interest in the company. Other investors provided the remaining funding.

Crescent Point said it expected Shelter Bay to drill 40 gross horizontal wells to the Bakken in 2008 and the same number in 2009. For wells on farm-out land, each company would hold a 50% interest.

In its 4Q 2009 report, Crescent Point said Shelter Bay drilled five Bakken horizontal wells on farm-out lands during the quarter.

Shelter Bay drilled another 19 wells on other Bakken properties. It also acquired freehold leases on more than 30 sections in the Viewfield Bakken trend and identified more than 66 net, low-risk drilling locations for the Bakken.

An independent engineering firm estimated proved and probable reserves on that land at 5.5 MMboe.

The additional properties gave Shelter Bay more than 450 locations in the Bakken and Lower Shauvanon oil plays, and the company's directors approved a capital budget of $192.2 million ($194 million) for 2010. The board directed more than 95% of that money to drilling and completions, with 85% of that funding going to the Bakken and 15% to the Lower Shauvanon.

Shelter Bay planned to drill more than 136 gross wells in both of the two formations in 2010 and predicted its production would average 7,500 boe/d during the year with an exit rate of more than 9,000 boe/d.

Spartan Exploration Ltd.

Spartan Exploration Ltd. went public in January 2010 as it acquired all of the outstanding stock of Aztek Energy Ltd. and started trading on the Toronto Stock Exchange.

The company's primary focus centered on the Cardium oil resource play in the Pembina area of Canada, but it also held property in the Bakken play in Saskatchewan. It budgeted 85% of its capital expenditures for 2010 on the Cardium play and anticipated drilling eight net horizontal wells. It drilled the first of those wells in 1Q 2010 and planned to put the well on production in 2Q 2010 at a rate of 300 b/d of oil. It also drilled and completed a Bakken horizontal well in the Viewfield area. That well went on production in February 2010 at a rate of 150 b/d of oil, 59 b/d, net to Spartan.

The company's average production for the quarter was 387 boe/d with 83% of that production coming from liquids.

TriOil Resources Ltd.

TriOil Resources Ltd., with a new management team established in January 2010, with Russell J. Tripp as president and chief executive officer, set its sights on the Cardium, Sanish, Bakken, and Pekisko light oil resource plays in Alberta and southeastern Saskatchewan, and started drilling horizontal wells.

Since its recapitalization in January, the company acquired Canext Energy Ltd. with 1,000 boe/d of production, acquired 54 gross, 40.7 net, sections in the Cardium play in southern Alberta, changed the company name to TriOil from One Exploration Inc., and drilled six (1.8 net) horizontal Sanish, Bakken B, and Pekisko light oil wells.

In April, the Sanish wells were in various stages of completion, a Bakken B well was awaiting completion, and a Pekisko well was being equipped for production.

Production totaled 1,400 boe/d and TriOil held 130,000 net acres of undeveloped land.

The company's Sanish, Bakken, and Midale properties at Tableland totaled 60 gross, 20.5 net, sections. The company drilled five gross, 1.5 net, wells in 1Q 2010 and put its first Sanish/Three Forks well on production in April 2010. That well tested for an average 186 b/d, 56 b/d net, of oil over its first 30 days online with a 65% water cut at the end of that period. The company completed the well with a 27-stage frac job.

The company held interests ranging from 30% to 50% at Tableland, with options to farm in on additional adjacent properties if it paid 50% of costs to earn a 30% working interest in eight sections per well.

It planned seven horizontal wells on the Tableland property during 2010, and had started drilling the fifth well in that series by April. Depending on results, it could add another 10 wells to that 2010 program in the second half of the year.

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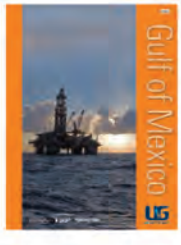

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Consortium Seeks Best Practices

A consortium of operators and service companies has collaborated to develop best practices for developing Bakken wells. Among these practices are critical completion and stimulation activities.

By Dick Ghiselin, Contributing Editor

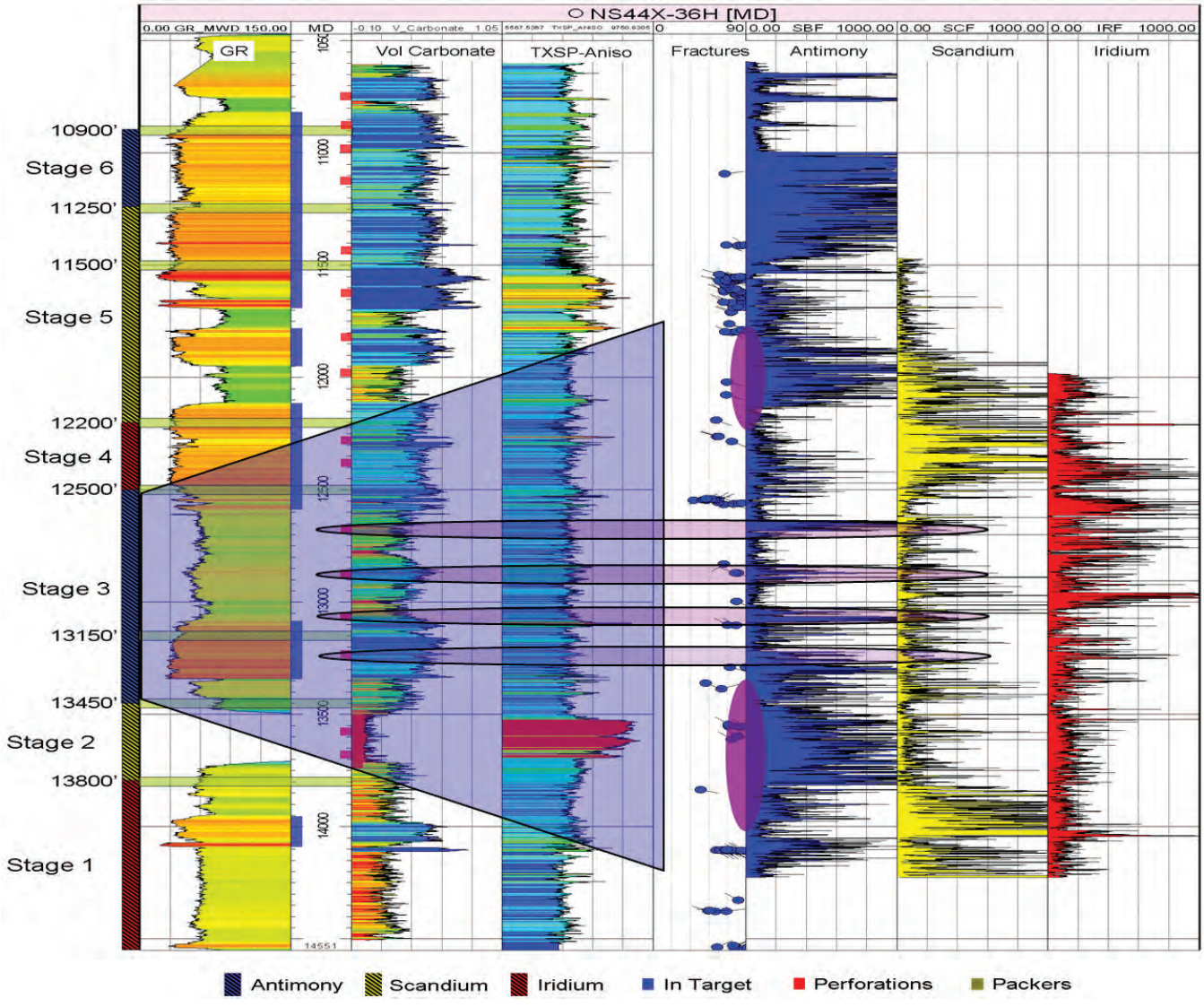


Figure 1. Nesson State 44X-36H well multi isotope RA tag. *(Images courtesy of Schlumberger)*

As Bakken activity migrated eastward from Montana into North Dakota between 2002 and 2005, players and participants encountered extreme heterogeneity in Bakken geology. However, the fact that the Bakken's areal extent was significantly larger in North Dakota encouraged the formation of a joint consortium of operators, service companies, and academia to study the problem with the goal of possibly developing a better understanding of the play.

The consortium sought to shorten the learning curve on the economic exploitation of the Bakken play by drilling and completing a series of wells under tightly controlled conditions and sharing the result with the members.

One of the most costly, but also most potentially rewarding, well construction activities can be the completion and stimulation phase. The technology involved in this phase is extensive, and actually begins way in advance of actual completion activities. Proper well placement and formation evaluation are fundamental pre-requisites to a good completion. Consequently, to achieve the desired end result, the consortium sought to shorten the learning curve on the economic exploitation of the Bakken play by drilling and completing a series of wells under tightly controlled conditions and sharing the result with the members.

The Bakken Research Consortium was formed in 2007 and its founding members included Headington Oil Company and Schlumberger Data & Consulting services (DCS). In 2008, XTO Energy Inc. purchased Headington's Williston Basin assets. Meanwhile, the consortium grew quickly to its present mix of seven operators and four technical contributors. Besides XTO/HOC, the operators included Hess Corp., Continental Resources Inc., Brigham Exploration Co., Encore, Petro-Hunt LLC and Whiting Petroleum Corp. In addition to Schlumberger, the technical contributors included The Department of Energy, Terrascience Ltd., and Microseismic Inc. In addition, a grant of US $750,000 was contributed by The North Dakota Oil and Gas Research Council.

Ambitious objectives

The consortium elected to plan and drill three horizontal laterals side-by-side in the Middle Bakken. By careful analysis and meticulous record keeping during the planning, construction, completion, and stimulation of these wells, the members hoped to focus on seven specific issues facing Bakken players as they moved into North Dakota:

- Identification of Middle Bakken targets;
- Lateral placement;
- Prediction of fracture intensity and orientation;
- "Sweet spot" prediction;
- Optimized hydraulic fracture design;
- Real-time fracture mapping; and
- Reservoir extension feasibility.

Location is everything

As with any business venture, location plays a critical role. The Nesson Anticline runs north-south along the common border of Mountrail and Williams counties in northwestern North Dakota. The consortium leased section 36 of 156N-95W, on the eastern flank of the Nesson Anticline, to drill its science wells. To ensure all operators were treated equally, the working interest in the lease was divided into seven equal shares, one for each operator. Technology members were deliberately excluded. On the other hand, the operators shared 100% of the risk. Technology members were compensated for their services and were entitled to all information and a copy of the final report.

A vertical pilot hole was drilled and extensively cored and logged as a part of the initial information gathering and planning phase of the lateral well bores. Later, this pilot hole was sidetracked and became the middle one of the three lateral wells. The lateral wells were almost identical. They were spaced about 1,500 ft apart and extended about 4,000 ft to the west.

Pre-job modeling is essential

To achieve the project objectives, complete geological, petrophysical, and geomechanical analyses were required. Only with a high-quality mechanical earth

model (MEM) could the completion and stimulation phases be designed and executed. Most importantly, only with these measurements and modeling could actual results be explained with sufficient certainty that they could be defined by a set of sustainable rules that would provide useful knowledge for future exploitation of the Bakken.

A program of extensive conventional coring followed by high-tier logging services was planned. These would be conducted initially in the vertical pilot hole. Later, as laterals were drilled, the logging program could be modified to add or remove services based on the results from the pilot hole.

Sophisticated logging program run

The initial logging program was designed to fully characterize the matrix mineralogy, porosity, and permeability, as well as its mechanical properties, including stress state. Evaluation included the Three Forks Formation lying just beneath the Bakken and the Lodgepole Formation lying just above the Bakken. These were included for two different reasons. The Lodgepole is typically wet, and no one wants stimulation fractures to propagate upward into the Lodgepole. On the other hand, the Three Forks is hydrocarbon-bearing, and everyone was interested to know if Three Forks targets could be included in Bakken drilling or stimulation plans.

In the pilot hole, triple-combo (resistivity/density/neutron) logs formed the backbone of the formation evaluation. They were augmented by the Sonic Scanner acoustic scanning platform, the ECS elemental capture spectroscopy sonde, and the CMR combinable magnetic resonance tool.

While the whole core was being analyzed by TerraTek Geomechanics Laboratory of Excellence, using X-ray diffraction imaging, petrophysicists were focusing on the complex lithology and mineralogy revealed by the triple-combo and nuclear spectroscopy logs. Ultimately, the core and log results were correlated to create a validated mineralogy characterization. The results from the magnetic resonance tool were used to determine the porosity and permeability of the Middle Bakken and the Three Forks formations. CMR results are independent of lithology so a valid cross-reference for porosity and pore-size distribution was obtained.

With this information, effective porosity, irreducible water saturation and permeability were estimated. The result of these determinations was a proxy for sweet spot identification and classification as the laterals were drilled. By correlating certain mineralogy presence with permeability and pore size, the most highly productive zones could be discriminated from zones of marginal potential. For example, zones containing quartz or dolomite tended to have better porosity and permeability, while those with high percentages of clay, feldspar,

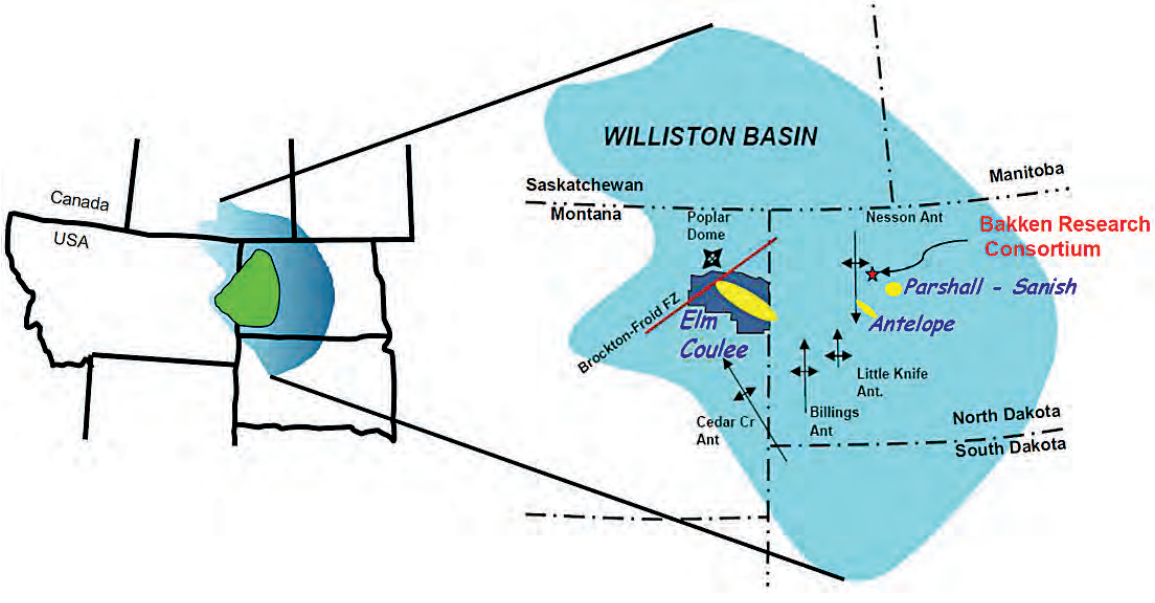


Figure 2. The Bakken Research Consortium drilled four wells in section 36 T195N R95W in northwestern North Dakota.

Since fracture propagation plays such a significant role in understanding how best to complete Bakken wells, the decision was made to carefully monitor the stimulation phase using seismic array technology.

and limestone were less promising. Natural fractures were investigated with the image log, the FMI fullbore formation microimager. Natural fractures can contribute to local permeability and some secondary storage.

Hydraulic fracture treatment fine-tuned with log data

Critical parameters affecting drilling and stimulation are local stress orientation and fracture containment. The Sonic Scanner analysis provided this information and its predictions were cross-checked with core analysis results. The Sonic Scanner also provides excellent information on formation anisotropy. This information was used to plan the multistage hydraulic fracture stimulation completion in the laterals. The ability to make anisotropic stress measurements represents a huge leap in information accuracy and quality compared to previous acoustic logging techniques which were constrained by the assumption of isotropy.

To achieve maximum reservoir contact, it is most desirable to create a large number of closely spaced transverse (perpendicular to the hole axis) fractures. Experience has shown that closely spaced shallow fractures are preferable to widely spaced deep ones. To have a chance to create fractures that will avoid propagating up into the Lodgepole, but have a chance to propagate down into the oil wet Three Forks, the anisotropic mechanical rock properties must be known in advance.

In the area studied by the consortium, it was concluded from the image log that the natural fractures would not contribute to production. The drilling-induced fractures confirmed the horizontal stress orientation, thus helping in staging the stimulation design. It was also observed that by understanding the relative strength of the Upper Bakken and Lower Bakken members, it was possible to predict the preferential propagation direction of a hydraulic fracture. For example, if the relative strength of the Upper Bakken was greater than that of the Lower Bakken, there was a higher likelihood that a fracture initiated in the Middle Bakken would propagate downward to intersect the Three Forks, and this would have a better chance of draining both formations. Completing both zones is challenging, but the ability to determine stress anisotropy definitely moves it into the realm of possibility.

Microseismic monitoring is extensive

Since fracture propagation plays such a significant role in understanding how best to complete Bakken wells, the decision was made to carefully monitor the stimulation phase using seismic array technology. Schlumberger deployed a 16-geophone tool within the Middle Bakken of the middle lateral. The triaxial geophones were spaced at 100-ft intervals to monitor the treatments of the two outside lateral wells in real time. At the same time, Microseismic Inc. deployed 24,000 conventional single component geophones across the ground surface above the three wells. The third technology provider, Terrascience Ltd., drilled 21 shallow holes of about 300 ft deep; it grouted a triaxial sensor in each. Lastly, the Department of Energy (DOE), through its Lawrence Berkeley Laboratories, installed three triaxial sensors grouted into place at 500-ft intervals in each of three vertical boreholes which it drilled to a depth of about 1,500 ft.

All of these devices were intended to record any microseisms produced in conjunction with the hydraulic fracturing operations performed on the two outside laterals. The purpose of using four different microseismic monitoring techniques was to ensure that the fractures were properly characterized, and to get an idea which, if any, technique offered the most overall advantages for use on subsequent fracture treatments.

Great care was taken to calibrate the microseismic arrays. First, a velocity model was generated from the Sonic Scanner data taken in the pilot well. Next, a test perforation shot was made at a known location and at a known time so each array could establish a T-zero benchmark and directly confirm

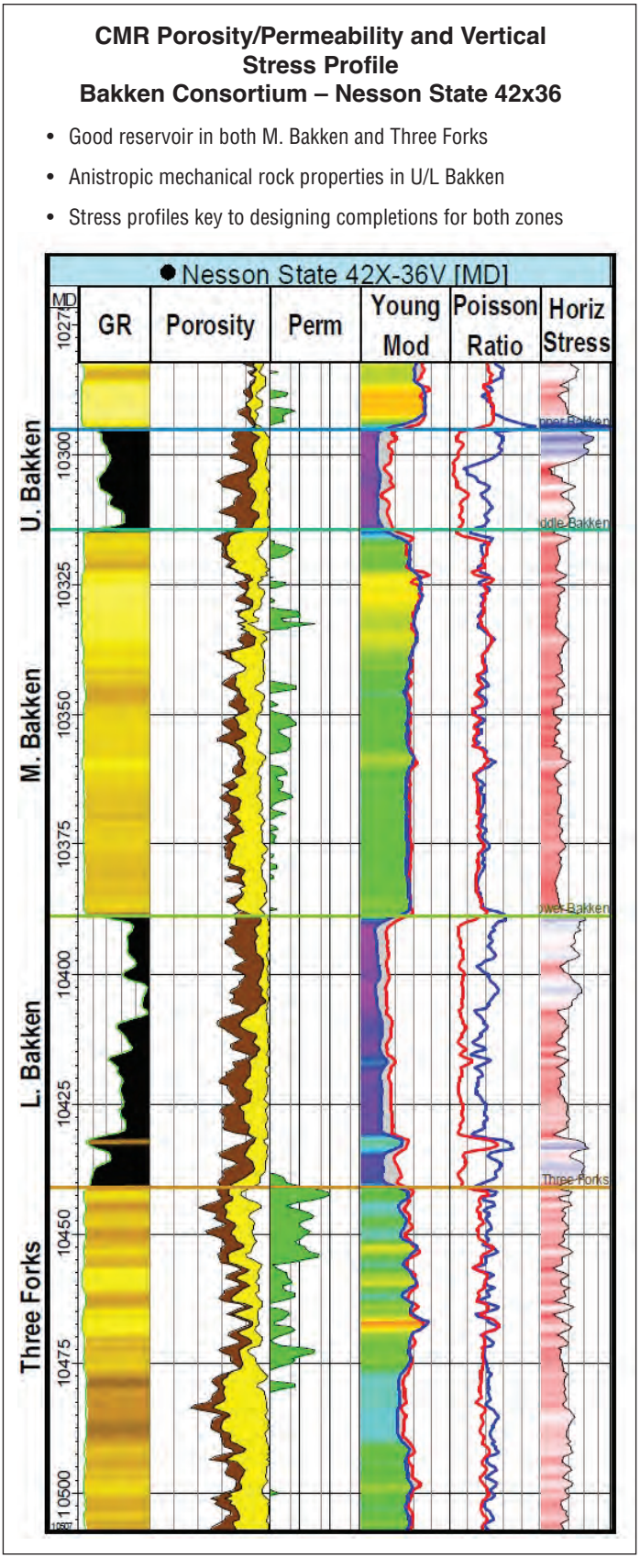


Figure 3. Integration of petrophysical properties with stress profile to highlight recommended completion.

the validity of their velocity model for both compression and shear waves. This process is used to confirm that the microseismic arrays can accurately record and locate the microseisms generated, as the treatments are pumped.

Also, the system calibration gave participants "ground truth" by which they could check the quality of seismic data recorded during the actual frac job. Experience has shown that microseismic data can contain erroneous events and noise. The benchmark data was useful in identifying the bad data points so they could be removed from further analysis.

In addition to microseismic monitoring, the decision was made to tag each frac stage with a different radioisotope tracer so the resulting stimulation could be analyzed for flowback using a spectral gamma ray log after treatment. Although the calibrated microseismic patterns from the various monitoring programs provided a depiction of 3-D fracture propagation, it was verified by subsequent correlation with the distribution of radioactive tags for each stage. Both the fluid and the proppant were tagged; the former with a chemical tag and the latter with radioisotopes so flowback results could be analyzed.

The radioactive tracer technique provided ample proof that the treatment was following the design which was based on the log and core analysis and modeling. For example, the flowback distribution measured on stage 3 of the southernmost well matches the lateral bounds of the microseisms recorded when that stage was pumped. Also, there is good correlation between the cumulative flowback volume and the number of microseisms recorded for each stage.

Secondary proof of the robustness of the technique was provided by the simulation model that was based on the

microseismic mapping. When the well was placed on production, the production data matched simulation model results with only a 10% adjustment to permeability for a perfect fit. Finally, a very strong correlation was observed between the initiation of fracture height growth and the changes in frac fluid. Vertical frac growth occurred when the frac fluid was switched from slick water to cross-linked gel. Models of the Middle Bakken based on rock properties show the same reaction. In the models, slick water remains contained while the cross-linked gel initiates height growth.

Neither the DOE nor the Terrascience near-surface systems were able to record the microseismic events generated during the actual fracture treatment. The conclusion was that the attenuation through 10,000 ft of sediment was too severe. The Microseismic and Schlumberger systems both reported events, locations, and origin times. The microseismic events referenced in this article are from the Schlumberger subsurface recording system.

Variable completion techniques used to attain objectives

To get maximum benefit from learnings, it was decided to complete each of the two outside laterals differently so results could be compared. The northernmost lateral was a pre-perforated liner with no external wellbore isolation. The frac was pumped in a single continuous treatment without diverters. Pad stages were pumped and proppant ramp-ups were observed that correlated with these stages. Some ball sealers were dropped, but they created no noticeable pressure changes.

> The consortium wanted to ensure their data collection objectives were met and were reluctant to risk any action that might jeopardize getting quality data.

In the southern lateral, a traditional plug-n-perf technique was deployed. Eight swell packers provided external isolation, according to the original completion design, but when the time came to pump the treatment, the consortium members decided to reduce the treatment to six stages by combining two of the stages.

Both the northern and southern wells were completed using a hybrid fluid design. Slick water was used for the pad and first proppant treatment and cross-linked gel was used for the remainder. In all, only 300,000 lb of proppant was pumped — much less than normal — as the consortium wanted to ensure their data collection objectives were met and were reluctant to risk any action that might jeopardize getting quality data.

Fracturing interpretation yields three conclusions

The combination of microseismic fracture mapping, radioactive, and chemical tagging allowed extensive interpretation of the completions of the various stages.

• **Near wellbore fracture initiation.** Figure 1 shows the results of the fracture initiation on the consortium southern lateral well bore from multiple isotope RA tagging. The vertical ellipse annotations on this figure highlight the RA signature of longitudinal fracture initiation along the well bore. The horizontal ellipse annotations point out likely transverse fracture initiation signatures. These transverse signatures, in many cases, correspond to where perforations shots were placed along the well bore during the plug and perforating staging.

This observation supports the theory that perforation penetration into the rock can create weak points (except in high stress areas) in the rock and be used to influence where and how fractures initiate. In previous work the issue of the influence of hoop stress anisotropy on fracture initiation had been discussed. The consortium results reinforce such theories. In the consortium wells the low angle orientation in relation to maximum horizontal stress seems to have encouraged some longitudinal fracture initiation. This likely caused some communication across swell packers in the southern lateral well bore. For future well applications either a more transverse wellbore orientation or longer spaced staging would be recommended.

• **Far field fracture complexity.** Once the frac-

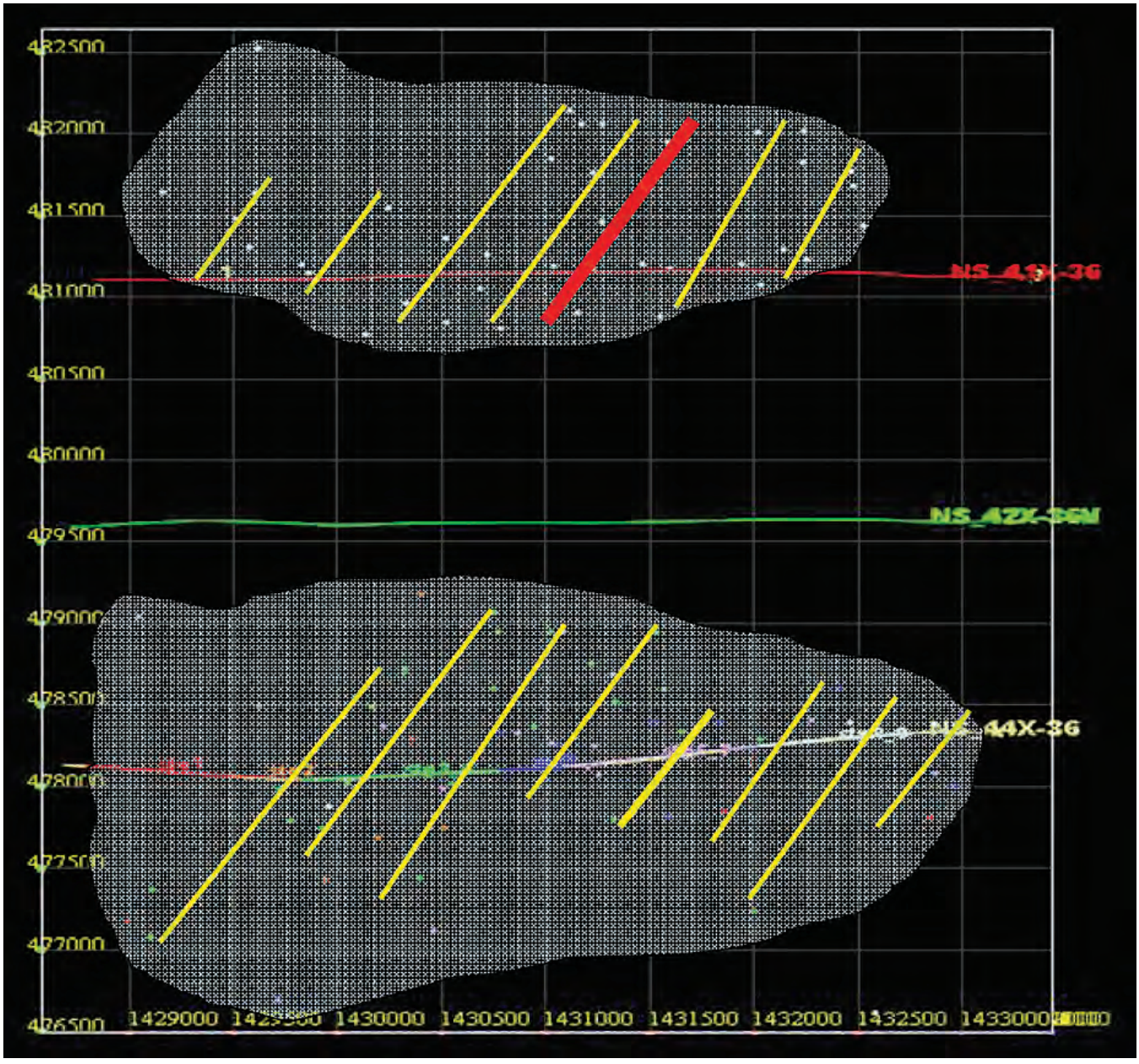


Figure 4. Microseismic fracture mapping of both the northern and southern laterals scaled to match reservoir simulator.

ture propagates beyond the near-wellbore region its propagation is more influenced by the far field stress and by the presence and orientation of natural fractures. According to the microseismic data, there was a strong correlation between fracture fluid viscosity and the ability to generate multiple closely spaced fractures. Once the cross-linked gel fluid was initiated, the microseisms associated with the creation of multiple closely spaced fractures subsided in favor of more widely spaced fracs.

The implication of this observation is that even though some parallel closely spaced fractures are being created (according to the microseismic) their width is insufficient to admit even the finest mesh proppants. Accordingly, in the Bakken it was concluded that creation of complex propped fracture patterns is unlikely — the proppant will stay in the main fracture. Therefore, it may be better to design fracs with larger mesh proppant to give maximum conductivity to the principle fracture plane and without regard to the complex swarms of narrow fractures.

• **Fracture height growth.** Because of the implications (bad) of the Lodgepole Formation and (good) of the Three Forks Formation, a thorough understanding of fracture height growth is required. The data from the three test wells indicated that the slickwater frac would stay in the Middle Bakken, but the cross-linked gel frac had the potential to grow upward risking intersection with the Lodgepole. Fortunately, the main direction of growth of the cross-linked gel fracs was downward, giving a better than even chance to intersect the Three Forks.

The implication of these conclusions is that all factors must be taken into account during fracture design: Middle Bakken thickness, proximity of the Lodgepole and Three Forks formations, relative position of the lateral within the Middle Bakken, and a thorough foreknowledge of anisotropic stress patterns and relative rock strengths in all three members of the Bakken Formation. The key parameter seems to be the Middle Bakken thickness. It has been stated that net frac pressure in an 80 ft thick Middle Bakken zone would only reach 250 psi, but in a 40 ft thick zone would ramp up to more than 1,000 psi, greatly increasing the chances it would propagate outside the reservoir boundaries. It has even been postulated in some operators' engineering departments that it might be better to target the Three Forks with the well bore in the first place and attempt to frac upwards to intersect the Middle Bakken.

It was quite fortunate that the fracture designs were hybrid with both thin slickwater fluids and corss-linked gel systems, because there were two distinctly different viscosity data points to match. The fact that the planar fracture height growth simulation, matched the microseismic results for both the slick water and the cross-linked gel fracturing fluids, provided confidence in the stress models used. This was one of the most significant findings of the consortium for completions optimization.

Fracture length seems to have an inverse relationship to fracture height growth. When slickwater treatments were modeled they seemed to achieve deep penetration without height growth out of the Middle Bakken. A conclusion is that perhaps a hybrid design offers the best of both worlds — deep penetration from a slickwater initiation followed by controlled height growth from a cross-linked gel tail-in.

No one size fits all

Many valuable conclusions have been drawn from the work of the Bakken Research Consortium that will benefit all players as they seek to exploit the play in more complex geology. The conclusions can be summarized as follows.

In the consortium hydraulic fracture treatments, both longitudinal and transverse fracture initiation was observed. From other experience it seems that placing the lateral normal to the maximum horizontal stress would help encourage more transverse fracture initiation. There is also evidence that perforations penetrating into the formation can help bypass the hoop stress around the well bore and create weak points for transverse fracture initiation.

Microseismic interpretation indicates that fractures generally propagate in multiple parallel planes. Fluid viscosity, net fracturing pressure, and fracture height growth seem to influence how closely spaced the fractures will occur. Cross planar complex fracturing and complex proppant transport in this area is unlikely.

Measuring an accurate stress profile from vertical pilot holes, and in particular measuring the anisotropic stress of the upper and lower Bakken shales are key to understanding the nature of the fracture geometry. This information can aid in determining the optimum fracture size, the type of fluid to use, and even optimum placement of the lateral.

Microseismic monitoring is an important tool for understanding and optimizing fracture completions in the Bakken Shale. But a multidisciplined integrated approach is critical to getting the most useful information out of this data.

The consortium locations were about 6 miles east of the Nesson Anticline, and natural fractures did not play an important role in this area. However in many other areas of the basin where there is more structure, natural fractures can influence productivity, fluid leakoff, and pressure dependence. In these cases an image log can be used to quantify the fracture density the apertures and the orientation, which would be incorporated into a system model for completions optimization.

References available

Bakken Bytes

Service providers active in the Bakken report their latest recommendations for dealing with the play's challenges.

By Dick Ghiselin
Contributing Editor

In a companion article, we describe the efforts of the Bakken Research Consortium. Seven operators pooled their resources to evaluate technical solutions to Bakken development with the idea of defining some best practices to improve the odds of constructing and completing a successful well. One of the conclusions of the study was that no amount of advanced completion and stimulation technology can significantly improve production without thorough advance planning and evaluation. Technical success depends on knowledge and understanding. Otherwise, the completion is a shot in the dark. Here is what several experts say.

The top five issues

The rig count for the Williston Basin, the location of the Bakken play, has increased rapidly in the past year. From a total of 36 rigs in June 2009, there are now well over 100 rigs in the basin. This increase in activity has pushed service company resources in the area to capacity.

With the increase in demand on service supply resources, effective resource allocation, and optimized completion, designs are essential. One significant challenge in this heightened activity environment is that completions crews must be supplied with large volumes of varying types of refined proppant and the necessary equipment to optimize the implementation of the fracture treatment. It is therefore more critical than ever to ensure that well placement is accurate to maximize potential returns, avoid unnecessary re-works, and increase efficiency.

Exploiting the play requires horizontal laterals to be drilled from 4,500 to 10,000 ft, starting at approximately 9,800 ft true vertical depth. Accurate and completely understood well placement is crucial to running effective fracture treatments in a tight rock environment, and Schlumberger's local insight backed by global expertise and innovative technology provides answers to increasingly complex challenges in the Bakken Shale.

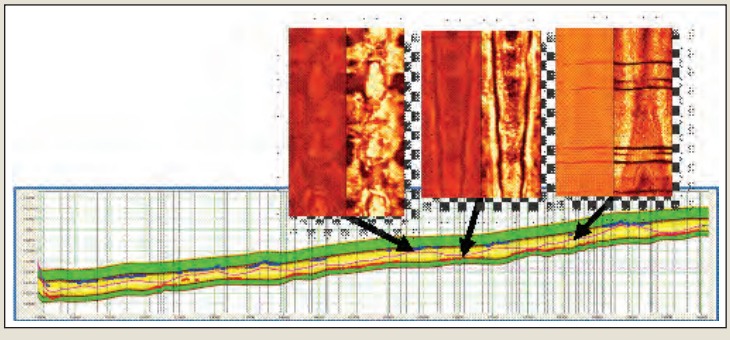
Many operators are utilizing the Schlumberger PowerDrive rotary steerable system to provide advanced well placement control while delivering a completely smooth well bore that enables single-trip, trouble-free completion installations.

Customers are using the Schlumberger Sonic Scanner acoustic scanning platform to provide a 3-D rock properties evaluation, which is then programmed into an optimized fracture treatment design.

— Mike Brunstein, *vice president, Sales and Marketing, Rockies Region, Schlumberger*

Swellable packers

Over the last two years, the major trend in Bakken Shale completions involved pumping more hydraulic fracturing stages in a single lateral. In fact, some operators are currently pumping more than 30 stages. The vast majority of the laterals have un-cemented liners in them and use some form of external packer system to help compartmentalize the openhole section. There is currently a split in completion types between operators using sliding sleeve technology and others using plug-n-perf, with some using a combination of the two.



InSite AFR image of different sections in a Bakken well. *(Image courtesy of Halliburton)*

For annular isolation, Halliburton recommends using the Swellpacker isolation system. This system does not require mechanical movement to extend the packer elements and, since the elements swell, they conform to any wellbore irregularities. To date, over 30 Swellpacker systems have been run in a single well bore.

Until recently, sliding sleeve technology has been limited to 10 stages or less. Halliburton has enhanced the Delta Stim completion service to enable more than 20 sliding sleeve sys-

tems for accurate fracture placement in horizontal wells with 4½-in. casing. The technology significantly reduces completion time when a large number of stages are pumped.

Another important development has been in the use of wellbore imaging to help determine how to compartmentalize and stimulate the well. This is accomplished using an InSite AFR azimuthal focused resistivity tool either during drilling or on the wiper run. Significant change along a lateral can occur. It is important to determine how to best complete the different sections. Additionally, microseismic mapping can help evaluate completions in these different sections.

— Mike Eberhard, *technical manager, Halliburton*

Well quality

A primary challenge for operators in the Bakken oil play is to accurately place and complete extended-reach, horizontal wells. Weatherford drilling services, surface logging, and completion groups help Bakken operators meet this challenge.

The company's Revolution rotary steerable system (RSS) reduces stick-slip in long horizontal sections and leaves a gun-barrel-clean hole that is ideal for the extensive multistage fracs that are common to the Bakken. Motorizing the RSS significantly increases rate of penetration and yields impressive time-vs.-depth drilling curves. Weatherford's logging-while-drilling data enable precise geosteering through varied and thin zones.

Placed 30 ft behind the bit, Weatherford's Inc-Sonde tool provides real-time inclination measurements, including on-the-fly inclination while sliding and/or rotating. The tool can also reduce overall drilling time by eliminating the need for checkshot survey tools and extending the length of the survey station course. *(Image courtesy of Weatherford)*

Weatherford's Inc-Sonde tool enables inclination measurements at just the right place in the drillstring to maintain precise directional control without the complexity, cost, or motor option limitations of at-bit tools.

Traditional cost-driven mud logging services in the Bakken have been replaced with advanced wellsite geochemical analysis that adds significant value to operations. Weatherford's GC-Tracer surface gas analyzer differentiates fluid variation within oil shale which correlates well with different lithological regimes. Additional wellsite geochemistry offerings measure dolomite vs. limestone percentages; evaluate total organic content, free oil and kerogen quality; and perform elemental and mineral analysis. The company's capability enables completion recommendations based on fluid quality and elemental rock breakdown, which yields optimum placement of frac stages.

Weatherford's ZoneSelect advanced flow control selective fracturing system uses a proprietary composite opening ball to eradicate issues of frac sleeves failing to indicate they have opened. Thus far the company's SingleShot ZoneSelect frac sleeves have a 100% success rate in the Bakken.

— Paul Radzinski, *area manager, Rocky Mountain Region;* Diego Ortiz, *evaluation specialist, GC-Tracer Formation;* Scott Williamson, *Western Region Business Unit manager, Completions and Flow Control;* and John Tesone, *area manager, Surface Logging Systems; Weatherford*

Environmental concerns

Water shortages and the environmental impact of oilfield operations have always been important concerns for operators in the Bakken.

In Saskatchewan, shortages of fresh water resulted in development of BJ Services' Viking II PW (produced water) fluid that provides enough viscosity to carry proppant under typical Canadian Bakken downhole conditions while being compatible with local produced water of varying salinity. BJ researchers are continuing to optimize a formula that performs predictably with higher North Dakota Bakken temperatures and produced waters, which are typically higher in total dissolved solids.

At the same time, economics are encouraging operators to complete more wells, more quickly, which affects completion strategies, logistics and personnel issues across the play.

Attempts to perform simultaneous fracture stimulation operations on several neighboring wells have resulted in some success as treatments use residual stress interfer-

Results from simultaneous fracture stimulations on three wells in Montana demonstrate the potential benefits of these enormous operations, but the logistics are daunting. *(Photo courtesy of BJ Services Co.)*

ence between wells to extend the created fractures deeper into the natural fracture network. However, the logistics of these enormous operations are difficult to manage in the current drilling frenzy.

According to BJ, most of the players have 24-hour operations, affecting the personnel and equipment requirements as well as logistics.

Although some operators continue to construct individual wells with cemented plug-and-perf completions, the quest for quick completion has largely pointed to the use of frac sleeve-and-packer completion systems, such as BJ Services' DirectStim system. In addition, Bakken well construction is moving away from single-well pads toward multi-well "eco-pads" like those used in the Marcellus Shale in Pennsylvania or the Pinedale Anticline in Wyoming.

The number of stimulation treatments per well has also been increasing, from an average of eight to 10 stages per well last year to an average of 15 to 20 currently, with some as high as 40 stages in a well. Stimulation plans vary considerably through the play, with some operators using sand and others using ceramic proppant, particularly in deeper sections of the play.

— Don Purvis, *region technology manager, BJ Services*

Attacking well costs

After working nearly 60 years in the Williston Basin, Baker Hughes continues to reduce wellbore construction costs, lower cost-per-foot drilled, and minimize nonproductive time. Application-specific drilling technology delivers higher penetration rate with exceptional wellbore quality in any well profile. While-drilling formation evaluation technology and geosteering techniques offer better fracture orientation/identification and bed-boundary recognition. The company's directional drilling services accurately place the well bore in the reservoir and can deliver long lateral length and multilaterals.

Baker Hughes' multistage completion expertise enables the best possible reservoir performance for shale projects, as demonstrated late last year in a successful 24-stage completion in the Williston Basin for Whiting Petroleum Corp.

At the time, this was the largest number of stages ever run using a ball/sleeve method for isolation. The FracPoint EX multistage fracturing system in the Ogden 1-31H well allowed the single-trip isolation of 24 intervals with an 8,000-psi pressure rating while achieving high frac rates through all of the ball seats. Since this well, the company has worked with another operator to deliver a 33-stage well with record production results. For a recent 36-stage completion, production results are pending.

Baker Hughes applies selective hydraulic fracturing of the tight, thin layers in the Bakken Formation without fracturing unwanted portions of the complex rock network. Zonal-isolation for extended-reach wells optimizes fracture-treatment placement throughout an entire lateral length. Isolation packers and frac sleeves or packers and composite frac plugs enable enhanced production. Openhole completion technology ensures efficient fracturing at a lower cost to achieve completion and full production faster.

— Matthew R. Isbell, *director of marketing, HCC, Baker Hughes*

THE ULTIMATE GUIDE TO THE REGION

With activity in the Bakken/Three Forks heating up, this is the go-to resource for anyone working the Rockies or trying to get into the action.

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Bakken's Infrastructure Grows Up

Operators are working to ensure that transportation capacity is available for growing oil and gas production.

By Jeannie Stell
Editor, *Pipeline and Gas Technology*
Adapted from *Pipeline and Gas Technology,* June 2010

When energy folks talk about American oil plays, the Bakken Shale in the Williston Basin is invariably the top topic of conversation. It was a hot play a few years ago, and is only getting better.

From the production fairway, oil and natural gas operators are pushing the boundaries outward. Continental Resources Inc., Brigham Exploration Co., and EOG Resources Inc. are expanding into western North Dakota. Whiting Petroleum Corp. is pushing into southwestern North Dakota. Others are exploring across the Montana border.

As they and new entrants continue to drill, they are putting the play on the map in a big way. By 2009, North Dakota was fourth when ranking oil-producing states. At the time, the state was flowing some 79.7 MMbbl/year. By March 2010, production had increased to more than 277,000 b/d, or nearly 100 MMbbl/year.

According to the North Dakota Industrial Commission, the 112 rigs drilling in the state in 2Q 2010 were estimated to produce as much as 450,000 b/d in May 2010, which would average 164 MMbbl/year. While the total resource base for the Bakken and the Three Forks formations is still being studied, early reports indicate some 200 to 500 Bbbl in place.

As the play grows, moving oil to markets via rail and truck is still under way, but new pipelines are needed, despite the fact that pipeline capacity exceeds oil production in North Dakota. The same is true for gas pipelines.

A look at graphs of actual gas volumes at receipt points vs. selected pipeline capacities shows a variety of utilization.

Alliance-Mainline is nearly full on a continuous basis, although it does have some room to spare. The Viking-TransCanada Emerson was running at half-mast until March, when it ramped up to maximum, although it has since leveled off to about two-thirds capacity. The Great Lakes-TransCanada-Emerson receipt point shows major volatility throughout the latter half of 2009 and into 2010, but gas volumes increased to about 2 million dekatherms per day in May 2010, leveling at 80% utilization. The Northern Border-TransCanada-Port of Morgan facility has been underutilized since before June 2009, and continues to run at less than half capacity.

Build, baby, build!

It comes as no surprise that the governors of North Dakota and Montana support new infrastructure to get the valuable commodity to market and to encourage more oil production. Recently, North Dakota Gov. John Hoeven and Montana Gov. Brian Schweitzer met with TransCanada Corp. to discuss a possible "on-ramp" to its Keystone XL Pipeline for area oil producers.

TransCanada is planning an oil pipeline from northern Alberta to refineries in the Gulf Coast and would run close to the border of southwestern North Dakota and through Montana. If built, the line has a targeted service date of 2012.

Hoeven is also encouraging Enbridge Inc. to expand its pipeline capacity northward. Enbridge is evaluating its US $300 million Enbridge Phase 7 project, an expansion of some 115,000 b/d from the Beaver Lodge looping station in northwestern

North Dakota, through Stanley, to an existing portal at Berthold.

Elsewhere, Alliance Pipeline Ltd. recently completed construction of a new interconnect facility near Bantry, N.D., to connect to Pecan Pipeline Co.'s 12-in., 76-mile Prairie Rose Pipeline. The new interconnect provides a much-needed route to bring gas and gas liquids from the Bakken to market. The Alliance system runs through the Williston Basin and transports rich gas, allowing liquids to be extracted at the delivery point rather than near production facilities, thus reducing processing and transportation costs for producers.

"We are bringing EOG's gas into the Alliance system," said Tony Straquadine, government affairs manager for Alliance. "We take that into Chicago on our Mainline system."

EOG Resources Inc. injects gas with up to 1,500-Btu heat content. The rich gas is too high for a typical interstate pipeline, but Alliance is a dense-phase, or rich-gas, system that can take the gas to Aux Sable Liquid Products, a world-class fractionation and extraction facility.

"Coming out of North Dakota, that system is like a garden hose coming into a fire hydrant," Straquadine added. Alliance Pipeline operates at 1,900 lb of pressure, keeping the liquids entrained as gas, and moves 1.6 Bcf/day, on average, through a 36-in. line — hence the analogy. EOG has firm commitment of 40 MMcf/d on Alliance this year, but it will up that to 80 MMcf/d in 2011.

"We are custom-made for the North Dakota producers," Straquadine said. "You could argue that they could put in small processing facilities and process the liquids out near the field, but then how do they move their liquids? We take it whole to Chicago. Beyond the capacity that EOG has committed, we have 108 MMcf available to attract incremental associated-gas volumes out of the Bakken."

Pipeliners are working to expand and enhance takeaway capacity from the Bakken play.

North Dakota Natural Gas Processing, MMcf/d

Owner/Company	Facility	County	2010 Plant Capacity
Bear Paw/ONEOK	Lignite	Burke	6
Bear Paw/ONEOK	Marmath	Slope	7.5
Petro Hunt	Little Knife	Billings	32
True Oil	Red Wing Creek	McKenzie	4
Sterling Energy	Ambrose	Divide	0.5
EOG Resources	Stanley	Mountrail	0
Whiting Oil & Gas	Robinson Lake	Mountrail	35
Whiting Oil & Gas	Ray	Williams	10
XTO	Nesson	Williams	10
Bear Paw/ ONEOK	Grasslands	McKenzie	100
Hess	Tioga	Williams	120
Hiland Partners	Badlands	Bowman	40
Hiland Partners	Norse/McGregor	Divide	10
Summit Resource	Knutson	Billings	NA

Source: North Dakota Industrial Commission

The Alliance system was built 10 years ago to serve producers in British Columbia and Alberta to drive the rich gas into the processing facility in Chicago. "Now we have that new entry point in Bantry, N.D. Right place, right time," he said.

More pipelines

TransCanada plans to begin construction of the 30-in., 302-mile Bison Pipeline this summer to connect gas production in the Powder River Basin of Wyoming to Northern Border Pipeline in Morton County, N.D. The initial capacity of 477 MMcf could be expanded to 1 Bcf. It is set to come online in November 2010.

Williston Basin Interstate Pipeline Co. (WBI), the wholly owned gas transmission pipeline subsidiary of MDU Resources Group Inc., plans to expand its existing gas pipeline capacity by 33% in the Bakken in northwestern North Dakota. The expansion will add up to 30 MMcf/d to existing volumes for delivery to Northern Border Pipeline by adding facilities to an existing compressor station in northwestern North Dakota. The targeted in-service date is November 2011.

Along with the pipeline expansion project, WBI is also working with gas producers and processors to add additional natural gas receipt points to its system throughout the Bakken production area. An open season for the Bakken Expansion Project ran through June 2, 2010.

Bridger Pipeline LLC plans to extend its North Dakota oil pipeline transportation system. Shippers will transport oil from an origin near the town of Four Bears, N.D., to Belle Fourche Pipeline's Skunk Hill Junction and to Bridger Pipeline's Fryburg Station, the origin of Bridger's Little Missouri Pipeline. The new extension of the system is targeted to be in service during 1Q 2011 with an initial capacity of 40,000 b/d.

Enbridge Pipelines LLC (North Dakota) plans to proceed with its previously deferred Phase 6 expansion work west of Beaver Lodge Station in response to recent increases in receipts at its Alexander and Trenton stations, growing production in the area and significant interest expressed by customers. New pumping upgrades will increase capacity of the company's Alex and Trenton stations, from 93,000 b/d to about 127,000 b/d. The work will be completed in 2011. Enbridge recently completed a non-binding survey of interest for its Phase 7 development of additional pipeline capacity with priority transportation service from Beaver Lodge Station into Berthold, N.D., and from there into Cromer, Manitoba.

Rail terminals

In April 2010, NuStar Energy LP's St. James, La., terminal unloaded its first rail car shipments of Bakken crude from North Dakota. The company invested $2 million in its St. James facility so it can accept oil by rail in an effort to bring new sources of crude oil to an area that is quickly becoming the nation's leading crude trading hub.

Through its manifest-rail expansion, NuStar will have the ability to bring in 10,000 b/d as Bakken production.

Meanwhile, US Development Group LLC began construction on its new St. James Rail Terminal, an oil and condensate train-handling and distribution hub in the Gulf Coast region of Louisiana. The St. James facility is the company's first crude oil and condensate terminal. It will be developed in partnership with Plains All American Pipeline LP.

Served by the Union Pacific Railroad, the St. James Rail Terminal will be able to handle both manifest and unit-train shipments serving various oil-producing areas in the US and Canada, including the Bakken. The facility, with an initial capacity of 65,000 b/d, will include several miles of rail track and a fully automated 26-spot rail rack and is expected to be in full operation by summer.

Gas plants

North Dakota has 11 gas-processing plants currently operating within the state, but more capacity is on the way.

Oneok Partners will invest more than $400 million in new growth projects in the Bakken Shale. The company plans to add 100 MMcf/d of gas processing at its proposed Garden Creek plant in eastern McKenzie County, N.D. The facility and related expansions are estimated to cost from $150 million to $210 million and will double the partnership's gas-processing capacity in the Williston Basin by 4Q 2011.

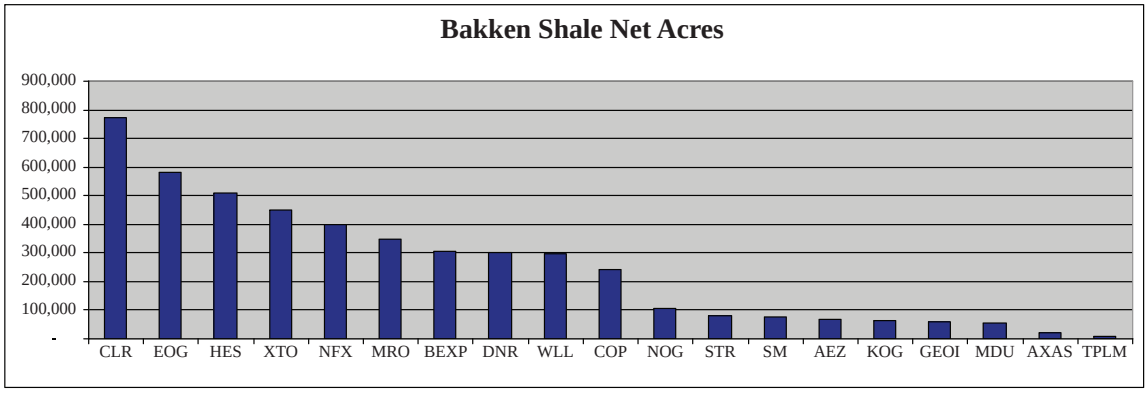
In April 2010, Hess Corp. filed a letter of intent with the North Dakota Public Service Commission to expand its Tioga gas plant, currently the largest and oldest gas-processing plant in the state. The expansion will more than double current throughput with new nameplate capacity of 250 MMcf/d. Hess plans to begin construction in March 2011 and have the $325 million facility operational by December 2012.

The Bakken Keeps on Rockin'

Operators look for ways to improve economics in a rising service-and-equipment-cost environment.

By Stephen Berman and Ray Deacon
Senior Research Analysts, Pritchard Capital Partners LLC

The Williston Basin contains the largest oil accumulation, the Bakken Shale, in the Lower 48. The Bakken Shale Formation is named after Henry Bakken, the landowner of the property where the first well was drilled, penetrating the Bakken in Williams County, N.D., in 1953. The basin is spread across the states of South Dakota, North Dakota, and Montana, and the Canadian provinces of Saskatchewan and Manitoba. An April 2008 US Geological Survey (USGS) report estimated that in North Dakota and Montana alone there are approximately 3.65 Bbbl of oil, 1.85 Tcf of natural gas, and 148 MMbbl of NGLs recoverable in the Bakken Formation, which is 25 times greater than the prior assessment done in the mid-1990s. Although production in the Bakken began back in the 1950s with a few vertical wells, and the first horizontal well (drilled back in 1987), production did not start in earnest until the discovery in 2000 of the Elm Coulee Field in Richland County, Mont. The play really took off in 2008, following the USGS assessment.



Note: NFX does not include the company's 224,000 net acres in the Alberta Basin.
(Source: Pritchard Capital Partners LLC)

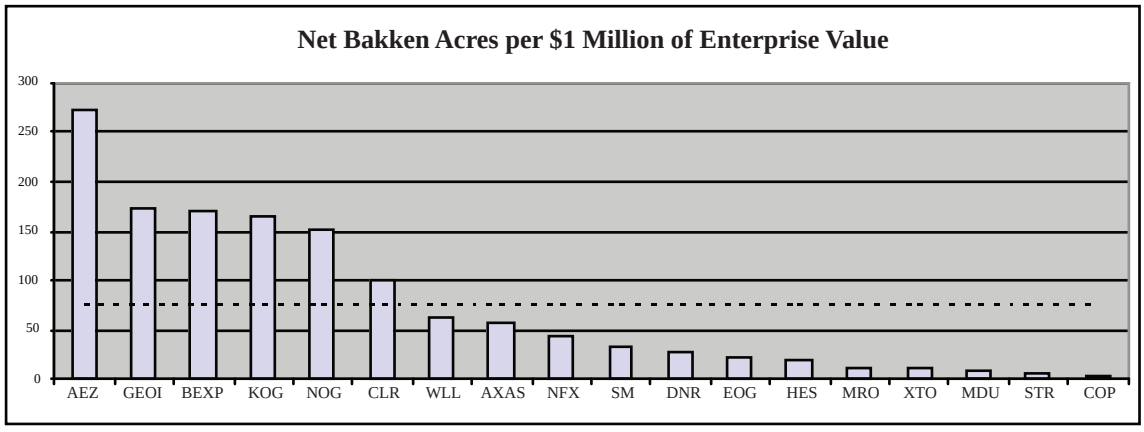
The Bakken is an unconventional oil play located at depths of approximately 8,500 to 10,500 ft and is a late Devonian, early Mississippian rock composed of three members – the upper shale, middle dolomite, and lower shale. The middle dolomite, commonly referred to as the Middle Bakken, is the primary oil reservoir with average porosity of 5%, low permeability of 0.04 md, and thickness up to 140 ft. Total thickness of the three members generally ranges from 150 to 200 ft.

Largely untapped, and potentially as big as the Bakken, are the Three Forks and Sanish formations. The Three Forks is a dolamitic rock located 20 to 30 ft below the base of the Lower Bakken, while the Sanish is sandstone that is sporadically wedged between the Three Forks dolomite and the Lower Bakken Shale. The Sanish sandstone, less prevalent in the Williston, is most prominent in the Antelope Field, at the southern end of the Nesson Anticline. Average distances between the middle of the Three Forks and the Middle Bakken range up to 100 ft. Early views by geologists and oil companies were mixed as to whether the Three Forks was a separate oil-producing formation, or if it acts as a trap, catching oil that leaks from the Bakken Shale above. Recent efforts, however, led by Continental Resources Inc., suggest the Bakken and Three Forks/Sanish are separate reservoirs.

In April 2010, the North Dakota Industrial Commission released a report of a recently completed study by the North Dakota Geological Survey and Department of Mineral Resources concluding that the Three Forks Formation could yield as much as 2 Bbbl of oil. According to the report, there is a high likelihood that the expected ultimate recovery from the Bakken and the Three Forks combined is approximately 4 Bbbl of oil – 2.1 Bbbl from the Bakken and 1.9 Bbbl from the Three Forks Formation. Currently, there are 181 wells drilled in the Three Forks Formation. In January 2008, the Bakken and Three Forks accounted for roughly 26% of North Dakota's oil production. In two years, Bakken production increased by 360%, and now accounts for approximately 70% of North Dakota's oil production.

Although most of the Bakken activity is in the Williston Basin in North Dakota and Montana, sev-

Note: NFX does not include the company's 224,000 net acres in the Alberta Basin. *(Source: Pritchard Capital estimates)*



eral companies, including Rosetta Resources Inc. and Newfield Exploration Co., are in the early Bakken exploration stages in the Southern Alberta Basin of Montana. The focus of the discussion here is on the Williston Basin.

Bakken economics

Drill and complete costs are typically running in the US $5 million to $7 million range, with lateral length and frac stages the main determinants in the final completion costs. The cost of a long lateral well has increased in most cases to plus or minus $7 million or more, from the low $6 millions at the bottom of the cycle. Helping to drive completion costs higher are proppant prices. As laterals have gotten longer and the number of frac stages increases, the demand for ceramic proppants, the virtues of which are extolled by many operators in the play, has increased sharply. Ceramic proppant prices are ranging between $0.41 and $0.55/lb, with some operators experiencing a 40% increase in cost.

In a rising service-and-equipment-cost environment currently in place in the play, reducing the number of drilling days is one way companies can keep costs under control. Pad drilling, which companies like Continental and Kodiak Oil & Gas Corp. have begun to put into effect, can bring costs down by approximately 10%. During the 2009 downturn, when oil prices bottomed below $40/bbl, many companies were able to take advantage of lower rig rates and lock up long-term contracts, but with numerous companies accelerating their drilling plans, new rigs are pricing approximately 20% to 25% higher. As of late May 2010, there were 117 drilling rigs active in North Dakota, and expectations are that number will go to 150 or more by early 2011.

Several companies are working on ways to reduce transportation costs to improve economics incrementally. EOG Resources Inc. is now railing a high percentage of their oil to the Gulf Coast and receiving New York Mercantile Exchange pricing, for example. Despite the high cost of rail transportation, the netback has increased noticeably. Bakken differentials, on average, are running several dollars per barrel below where they were a year ago. New pipelines have been proposed to ensure that takeaway keeps pace with production – not surprising, given the returns available in the play. Another way that returns may improve is in the form of reduced water handling costs associated with the produced water, which currently account for a high percentage of the lease operating expenses.

Finding and development (F&D) costs in the Bakken are among the lowest of any play in the US. In Whiting Petroleum Corp.'s core Sanish Field, east of the Nesson Anticline in Mountrail County, N.D., using the company's average type curve estimated ultimate recovery (EUR) of 850 Mboe, F&D costs are $1.32/Mcf of gas equivalent using a standard 6:1 conversion ratio. Given that the Bakken is an oil play, using a 13:1 conversion ratio brings the F&D cost down to $0.61/Mcf of gas equivalent, approximately half or less of some of the top gas shale plays in the US. Internal rates of return (IRR) in this core part of the play at $70 oil are north of 200%, with the PV-10 value on a $5.5 million well running upwards of $15 mil-

North Dakota Bakken IRR Sensitivity									
		Oil Price ($/bbl)							
		$30.00	$40.00	$50.00	$60.00	$70.00	$80.00	$90.00	$100.00	$110.00
Well Cost ($mm)	$7.00	6%	17%	29%	43%	58%	73%	89%	106%	122%
	$6.50	7%	19%	33%	48%	65%	82%	99%	117%	136%
	$6.00	9%	23%	38%	55%	73%	92%	111%	131%	151%
	$5.50	11%	27%	44%	63%	84%	105%	126%	148%	169%
	$5.00	14%	32%	52%	74%	96%	120%	143%	167%	192%

(Source: Pritchard Capital estimates)

lion. Whiting believes that 18 frac stages in the east and central portion of the Sanish Field yield the best economics, while in the western portion of the field, up to 30 frac stages are needed to achieve optimal results. Continental, the largest player in the Bakken with close to 775,000 net acres, estimates an approximate 80% IRR on a $5.9 million, 24 frac stage long lateral, with an EUR of 518 Mboe and oil at $75. In its core area in Mountrail County, operated by privately held Slawson Exploration Co., Northern Oil & Gas Co. achieves payout in three to four months.

Moving west of the Nesson, Brigham Exploration Co., as of this writing, had drilled 23 consecutive solid long lateral wells, 17 of which were in its Rough Rider area in Williams and McKenzie counties, N.D. Operational advancements have been a big driver of lower F&D costs, as EURs have risen at a faster rate than well costs since 2006. Brigham's long lateral Rough Rider wells, with as many as 36 frac stages, had an average 24-hour initial production rate of 2,452 boe/d. A 600-Mboe Brigham well costing $7.2 million has an approximate 70% rate of return, with a PV-10 of $9.3 million and payout in 1.6 years, with a breakeven oil price around $30/Boe.

Most of the companies contacted by Pritchard Capital believe the Bakken play is moving towards 320-acre spacing (4 wells/1,280-acre spacing unit). With the now widespread belief that the Three Forks/Sanish is a separate reservoir, Bakken players could have up to an equal number of Three Forks locations, as well, depending upon how prolific it is on a particular company's acreage.

Assuming a 600Mboe EUR and an 80% first-year decline rate, Pritchard Capital computed IRRs at varying well costs and oil prices. As operators continue to perfect their drilling techniques, it is possible that IRRs could increase in the future.

On May 4 and 5, 2010, North Dakota held its quarterly state land oil lease auction which brought in a record $158 million. On average, the winning bid was $2,967/acre for roughly 53,275 acres for auction in 12 counties in western North Dakota. The May quarterly sale more than doubled the previous record of $71.5 million set in November 2009 ($1,214/acre, average). The highest acre bid was $12,500/acre for eight acres in Stark County. While the acreage was not located in a designated oil field, Whiting has a rig to the north. The high bids in McKenzie and Dunn counties were $5,500/acre, with Mountrail and Williams counties posting $7,200/acre and $7,100/acre bids, respectively.

Approximately 30% of domestic oil production comes from the Gulf of Mexico. The spill at Macondo and the resulting six-month moratorium on deepwater drilling, in conjunction with the uncertainty surrounding likely new regulations, is causing the market to look onshore for oily plays that are more stable to pick up the slack. Economics are top-notch, and many companies contacted by Pritchard Capital report they would remain that way even at $50 to $55 oil, making the Bakken a solid option for E&P investors. Barring a collapse in oil prices, the Bakken/Three Forks in the Williston Basin is likely to remain a hotbed of activity for years to come.

In two years, Bakken production increased by 360%, and now accounts for approximately 70% of North Dakota's oil production.

Additional Information on the Bakken

For more details on the Bakken, consult the selected sources below.

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