Bakken---Buzz-Buzz-Buzz

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ENERGY TECHNOLOGY COMPANY

Crude Oil Quality Association

Denver June 10, 2010
What are the facts?

What is the potential?

What is its quality?

Where does it go?
Every few weeks, someone gets a another chain e-mail about the Bakken Formation and the billions of barrels of oil the US is not tapping. The blame goes to environmentalists, the oil companies, politicians, and stupidity. Reserve numbers in the billions of barrels, even tens or hundreds of billions show up in press reports and blogs. Now the USGS has weighed in with a comprehensive assessment of the resource.

The Bakken Formation was formally described (named) by geologist J.W. Nordquist in 1953. His samples came from the Amerada Petroleum - H.O. Bakken #1 well on the Nesson Anticline in Williams County, North Dakota. Henry Bakken was the surface owner where the well was drilled.
BAKKEN FORMATION

Conventional oil underlying parts of Canada and USA—350 million-yr-old layer of rock

- Saskatchewan (SE corner)
- Manitoba (a smidgeon)
- North Dakota (most of it)
- South Dakota (but not all consider it a part of the Trend)
- Montana (1/3 of it)

Discovered in the 1950’s
BAKKEN FORMATION

Structures

- Lower Shale
- Middle Dolomite
- Upper Shale

Shales = deposited in deep marine conditions
Dolomite = deposited as a coastal carbonate bank during time of shallower water.
LAYERS/RESERVOIRS ARE

• **BAKKEN**
• **TORQUAY** and
• **THREE FORKS-SANISH FORMATION**
  Directly under the Bakken Formation

One of the earliest players was Shell. Original wells started well but soon fatigued too early leaving disappointment and exasperation.

The majors left to play in the GOM sandbox.
Willston Basin

- 15 primary producing formations including the Bakken.
- Sediments can be up to 15,000 ft thick
- Bakken itself reaches a maximum thickness of about 150 ft, but is thinner in most areas
- Depth to the top of the Bakken can vary from a few thousand feet in Canada to more than 10,000 feet in the deeper areas in North Dakota
- Age-Deposited during the upper Devonian and Lower Mississippian periods about 360 million years ago
Dolomite (pronounced /dɔləˈmeɪt/) is the name of a sedimentary carbonate rock and a mineral, both composed of calcium magnesium carbonate CaMg(CO₃)₂ found in crystals.

Dolomite rock (also dolostone) is composed predominantly of the mineral dolomite. Limestone that is partially replaced by dolomite is referred to as dolomitic limestone, or in old U.S. geologic literature as magnesian limestone. Dolomite was first described in 1791 as the rock by the French naturalist and geologist, Déodat Gratet de Dolomieu (1750–1801).
The experimental replacement of calcite and aragonite by dolomite under a variety of conditions indicates that dolomitization can take place in marine and lacustrine environments under two conditions:

• low dissolved sulfate concentrations and
• insubstantial contemporaneous silica diagenesis.

Common sites for dolomite formation are areas where the dissolved sulfate concentration is reduced by microbial sulfate reduction, through the mixing of seawater with large amounts of fresh water, or where low-sulfate alkaline lacustrine environments prevail. Even under these conditions, dolomite formation may be inhibited by the concurrent transformation of opal-A (amorphous silica) to opal-CT (disordered cristobalite and tridymite), whereas the subsequent transformation of opal-CT to quartz favors the formation of dolomite.
Vancouver - April 2010

“Saskatchewan posts strong sale featuring Bakken”

lively bidding

$190 mil in government land sale

sold 228 K acres @ $835/acre vs. $342 in 2009
Why the renewed interest?

Price of oil in recent years is $60-70-80/bbl (even $100 or more)

Suddenly, companies are showing great interest.

In terms of oil in place, Bakken is saturated.

In terms of quality, it is light and sweet, very marketable.

In terms of potential, only a small % is recoverable. Technology needs to unlock this potential.
First wells drilled in Saskatchewan were on land owned by PetroBakken (then Petrobank). Expectations and reality did not blend. PetroBakken experimented with technology.
“The advent of horizontal wells and the application of the staged hydraulic frac that PetroBakken has been doing through Packers Plus cracked the nut on how to get oil of the zone.”
crude in the Bakken is extremely light and marketable. And in terms of potential, let’s look at it this way: if just a small percentage of the oil in the Bakken is recoverable, the province of Saskatchewan—already the second largest oil-producing province in Canada—would probably double their existing reserves.

The challenge with the oil in the Bakken, however rich in resources it may be, is that it is extremely difficult to extract. In the simplest of terms, the Bakken formation is a sequence of siltstones and sandstones that are sandwiched between two layers of organic rich shale. It is similar to an Oreo cookie, in that there is a layer of black shale above and below the siltstone, or the sweet stuff, which contains the oil. The siltstone has a very low porosity and permeability, which means the oil located in the pores of the rock does not readily flow out of the rock. There is a vast amount of oil generated in the Bakken shale adjacent rock to the siltstones encased in these sheets of non-porous Bakken shale. Because of the poor permeability of these siltstones containing the oil, traditional drilling methods cannot yield adequate quantities to justify or offset the cost of drilling.

Reservoir like an Oreo.
Directional horizontal drilling technology was the most recent technological break-through that has facilitated the latest enthusiasm for the Bakken.

1 mile deep
1 mile across
bilateral wells

30-stage fracs/well = up to 60 K b/d

In 2008, 8-stage frac was norm with 100 b/d production
The Bakken is truly huge.

USGS “503 billion barrels”

Arab Lt/Ghawar in Saudi Arabia = 125 bil

Oil companies, including the majors, have known for some time that oil exists in the Bakken, but the problem was getting it out. The few wells that were drilled in the years prior to 1996 produced some oil but soon “Gave up the Ghost”, so to speak. The majors, such as Shell left and put their money into the Gulf of Mexico.
Key Parameters:

- **Porosity**—space in the rock to store the HCs
  - Good = 20-30+ %

- **Permeability**—easily fluid can flow through the rock.
  - Good = 1 to 5 darcies or more
  - (ie, 1000-5000 millidarcies)

[These high porosities and permeabilities can be found in many world class prolific oil and gas fields, such as the offshore Gulf of Mexico, the North Sea, and Saudi Arabia.]
Bakken Shale, along with formations like the Barnett, Fayetteville, and Woodford shales

- **Permeabilities are low**
  0.00001 to 0.01 millidarcies

- **Porosities are low**
  near zero to maybe 10% or a bit higher.

Good Permeabilities = 1000-5000 millidarcies

Good Porosity = 20-30+%

[Porosity and permeability can vary widely and unpredictably over short distances. Dry holes have been drilled next to prolific producing wells. This phenomenon is one of the primary risks that oil producers take when they drill wells, especially in new areas or highly variable reservoirs.]
Natural Fractures

- Low Porosity

- But can have **Permeabilities** one to several orders of magnitude greater than the rock matrix.

Most of the better wells in the Bakken have encountered abundant natural fractures.
3 to 4.3 Billion Barrels of Technically Recoverable Oil Assessed in North Dakota and Montana’s Bakken Formation—25 Times More Than 1995 Estimate—

Released: 4/10/2008

Contact Information:
Office of Communication
119 National Center
Reston, VA 20192

Results of the assessment can be found at http://energy.usgs.gov.
For a podcast interview with scientists about the Bakken Formation, listen to episode 38 of CoreCast at http://www.usgs.gov/corecast/.
Oil production from rocks of the Bakken Formation in North Dakota has been rising rapidly for the past three years. Data from: North Dakota Geological Survey.
Oil production from rocks of the Bakken Formation in North Dakota has been rising rapidly for the past three years. Data from: North Dakota Geological Survey.

Inflation Adjusted Monthly CRUDE OIL PRICES (1946-Present) in January 2010 Dollars

Source of Data:
Oil Prices: www.eia.doe.gov/cneaf/aer/d6/shorttermprices.html
CPI-U Inflation index: www.bls.gov
90% of the energy value is in the oil, rest in gas and NGL’s.

### Table 1. Bakken Formation, Williston Basin Province assessment results.

[MMOB0, million barrels of oil. BCFG, billion cubic feet of gas. MMNBNGL, million barrels of natural gas liquids. Results shown are fully risked estimates. F95 represents a 95 percent chance of at least the amount tabulated; other fractiles are defined similarly. TPS, total petroleum system; AU, assessment unit.]

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<th>Gas (BCFG)</th>
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<th>NGL (MMNBNGL)</th>
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Recap: Challenging Reservoirs

Estimated recoverable bbls - 4.1-5 billion barrels

Produced to date - 111 million barrels over past 50 yrs

Per-well production peaked in August 2005 at 116 b/d day

In October 2007, per well production avg 79 b/d
Bakken total = 0.4% of US oil consumption, or 0.6% of imports.
PetroBakken has been a pioneer in the field and has developed and employed technology to deliver commercial success.

Today, PetroBakken is drilling 128 wells/yr with plans to drill over 1300 locations for a total of 2600 wells—all horizontal. Their focus is the Lower Shaunavon formation of SW Saskatchewan and Viking Formation in W-central.

Current technology allows production at 60 K b/d. Saskatchewan is closing the gap with Alberta in terms of conventional oil production (in 2008, 1.61 vs 1.84 mil barrels.)

[BC also has shall plays.]
Montana – slower than N. Dakota counties:
- Montrail
- Dunn
- Mercer are the most active
Whiting Petroleum

Lewis & Clark Area – 250 Units / 500 Potential Locations

OBJECTIVE
Upper Three Forks along pinch-out of the overlying Bakken Shale

ACREAGE
Whiting has assembled 319,971 gross (202,367 net) acres in our Lewis & Clark prospect area in the southwestern Williston Basin.

This acreage position would allow up to 250 possible 1,280-acre spacing units within the prospective area:
- 123 units with > 50% WI
- 127 units with < 50% WI
- Average WI of 63%
- Average NRI of 54%

ECONOMICS
Well Cost: $6 MM per well
EUR: 330 to 420 MBOE

DRILLING PROGRAM
Current 13-well program will begin in Q1-10 with one additional rig planned for Q2-10 and a third rig in Q4-10. Planned CapEx for 2010 is $62 MM

FEDERAL 32-4H DISCOVERY WELL
IP: 1,970 BOE/D. Average rate during first 30, 60 and 90 days of production was 695 BOE/D, 531 BOE/D and 447 BOE/D, respectively.
• EOG Resources (EOG)--is generally regarded as being ahead of the other companies in developing and producing Bakken oil with 300,000 acres under lease and drilling multiple wells. EOG has said that Bakken has highest return of any of their properties
• Marathon Oil Corporation (MRO)
• XTO Energy – now owned by Exxon. Known as the shale experts! XTO has jumped onto the Bakken scene.
• Brigham Exploration Co.--- the hottest of the smaller oil companies working the Bakken Formation as experts in 3D seismic technology in finding oil at Bakken.
• Northern Oil and Gas--- has over 30,000 acres under lease and a heavy drilling program in progress.
• Whiting Petroleum Corp – wells drilled in Bakken are flowing
• Continental Resources --believed to be the largest (487,000 acres) lease holder at Bakken.
• St. Mary Land & Exploration (SM)
• Kodiak Oil & Gas Company --has no wells in the area, yet but has 38,000 acres under lease.
• Oneok Partners investing $200+ mil in 2010-11 (mostly gas).
• Baytex Energy Trust drilling in Three-Forks ND (250k acres with 300 b/d per well) and Viking in SW Saskatchewan
• etc
WHAT IS ITS QUALITY?

Great—Montana’s Elm Coulee produces 50k b/d of 40-42*API crude.

Quality differs by formation

Most large oil reserves have a gravity gradient—often 3-5*API in the same zone

Quality can vary by reservoir
Through the use of technology, U.S. oil and natural gas operators are converting previously uneconomic oil and natural gas resources into proved reserves and production:

- horizontal drilling,
- fracturing,
- completion technologies.

Bakken is not blazing into unchartered frontiers. Instead, success is coming from
- analysis of decades-old geologic data
- identification of uptapped resources, and
- use of new drilling (esp horizontal drilling) techniques and
- completion technology necessary to exploit them.

In short, it came from using technology to convert unconventional resources into reserves.
<table>
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<tr>
<th>Property</th>
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<th>Bakken</th>
<th>LSB/SES/</th>
<th>WTI</th>
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<td>40.90</td>
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DISPOSITION – CURRENTLY A PROBLEM

Infrastructure is limited.

- Canada: production is sold as LSB
- US side: there is one small local pipeline
  - some may get into ND Sweet
  - some into Rocky Mt Sweet
  - some into other local pipelines
  - rest is trucked
  - some is being railed to Cushing

- Eventually, PL to Cushing will be built
- Other PLs going west and south to get to the large GOM refineries as well as West Coast
The Bakken Rush is finally on in the US as well as in Canada.
Conclusion:

If this oil formation plays out toward the higher end of size and recoverability, it may change the geopolitics of oil and the economies of the US and Canada.

If difficult to extract, new technologies could still dramatically improve the recoverables.

The motivation to pull out another 100 bil bbls could be $9 tril at today’s prices.

Let the games begin.
Shale is a fine-grained, clastic sedimentary rock composed of mud that is a mix of flakes of clay minerals and tiny fragments (silt-sized particles) of other minerals, especially quartz and calcite. The ratio of clay to other minerals is variable. Shale is characterized by breaks along thin laminae or parallel layering or bedding less than one centimeter in thickness, called fissility.

Mudstones, on the other hand, are similar in composition but do not show the fissility.