Petroleum Geology of the Giant Elm Coulee Field, Williston Basin*

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Abstract

The Elm Coulee Field of the Williston basin is a giant oil discovery in the middle Bakken Formation (Devonian-Mississippian) discovered in 2000. Horizontal drilling began in the field in 2000 and to date over 500 wells have been drilled. The estimated ultimate recovery for the field is over 200 million barrels (31.8 million m3) of oil.

The Bakken in the field area consists of three members: (1) upper shale, (2) middle silty dolostone, (3) lower siltstone. The total Bakken interval ranges in thickness from 10 to 50 ft (3.1 to 15.3 m) over the field area. The upper shale is dark-gray to black, hard, siliceous, slightly calcareous, pyritic, and fissile. The shale consists of dark organic kerogen, minor clay, siltsized quartz, and some calcite and dolomite. The kerogen consists mainly of amorphous material, and the organic material is distributed evenly throughout the shale interval (not concentrated in laminations or lenses). The upper shale ranges in thickness from 6 to 10 ft (1.8 to 3.1 m) over the field area. The middle member consists of a silty dolostone and ranges in thickness from 10 to 40 ft (3.1 to 12.2 m). The lower member in the Elm Coulee field consists of brownish-gray, argillaceous, organic-rich siltstone. Burrowing and brachiopod fragments are common in the lower member. This facies is equivalent to the lower Bakken black shale facies on the northern side of the field and is interpreted to be an up-dip-landward equivalent to the deeper-water, black shale facies. The lower member ranges in thickness from 2 to 6 ft (0.61 to 1.8 m). Based on abundance of fossil content and amount of burrowing, the members of the Bakken are interpreted to have been deposited under aerobic (middle member, common burrows and rare fossils), dysaerobic (lower member, common fossils, lesser amount of burrows) and anaerobic conditions (upper member, rare fossils and burrows).

The main reservoir in Elm Coulee is the middle member which has low matrix porosity and permeability and is found at depths of 8500 to 10500 ft (2593 to 3203 m). The current field limits cover approximately 450 mi2 (1165 km2). The porosities range from 3 to 9% and
permeabilities average 0.04 md. Overall, reservoir quality improves upward as the middle Bakken has less mudstone matrix. The middle Bakken is interpreted to be a dolomitized carbonate-shoal deposit based on subsurface mapping and dolomite lithology. The main production is interpreted to come from matrix permeability in the field area. Occasional vertical and horizontal fractures are noted in cores. The vertical pay ranges in thickness from 8 to 14 ft (2.4 to 4.3 m). The Bakken is slightly overpressured with a pressure gradient of 0.53 psi/ft (0.02 kpa/m) spacing units. Long single laterals, dual laterals, and tri-laterals have all been drilled in the field. The horizontal intervals are sand-gel-water fractured stimulated. Initial production ranges from 200 to 1900 BOPD (31.8 to 302.1 m3 per day). Initial potential rates for vertical wells are generally less than 100 BOPD (15.9 m3 per day). The upper Bakken shale probably also contributes to the overall production in the field. The exact contribution is unknown but estimated to be less than 20% of the total production.

The Elm Coulee field illustrates that the Bakken petroleum system has enormous potential for future oil discoveries in the Williston Basin.

**Selected References**


Hester, T.C. and J.W. Schmoker, 1985, Selected physical properties of the Bakken Formation, North Dakota and Montana part of the Williston Basin: U.S. Geological Survey Oil and Gas Investigation Chart OC-126, 1 Sheet


**Website**

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ABSTRACT

The Elm Coulee Field of the Williston basin is a giant oil discovery in the middle Bakken Formation (Devonian-Mississippian) discovered in 2000. Horizontal drilling began in the field in 2000 and to date over 500 wells have been drilled. The estimated ultimate recovery for the field is over 200 million barrels (31.8 million m³) of oil.

The Bakken in the field area consists of three members: (1) upper shale, (2) middle silty dolostone, (3) lower siltstone. The total Bakken interval ranges in thickness from 10 to 500 ft (3.1 to 15.2 m) over the field area. The upper shale is dark-gray to black, hard, siliceous, slightly calcareous, pyritic, and fissile. The shale consists of dark organic kerogen, minor clay, silt-sized quartz, and some calcite and dolomite. The kerogen consists mainly of amorphous material, and the organic material is distributed evenly throughout the shale interval (not concentrated in laminations or lenses).

The middle member is rich in fossils and contains the target reservoirs of horizontal drilling. The middle member is a dolomitic limestone with low matrix porosity and permeability and is found at depths of 8500 to 10500 ft (2593 to 3203 m). The current field limits cover approximately 450 mi² (1165 km²).

The lower member is a siltstone with few fossils and has been drilled vertically. The average vertical pay is 8 to 14 ft (2.4 to 4.3 m). The Bakken is slightly overpressured with a pressure gradient of 0.53 psi/ft (14.7 kPa/m).

Unconventional, Continuous Tight Oil Accumulations

- Presence of planktonic algal spores (staurids), fish remains, cephalopods, ostracods, conodonts, and inarticulate brachiopods indicates marine environment.
- Shale: hard, siliceous, pyritic, fissile, organic rich (average 11.3 wt% organic carbon)
- Upper and lower shale: identical in lithology
- Upper and lower black shales: similar in organic richness
- Upper OM indicates anoxic conditions (amorphous-sapropelic OM; probably algal or phytoplankton origin)

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- IHS
- MJ Systems, TGS
- NDIC, North Dakota Geological Survey
- EERC, University of North Dakota
- USSS Williston Basin Team

Unconventional, Continuous Tight Oil Accumulations

- Pervasive petroleum saturation
- Mature source rocks
- Abnormally pressured
- Generally lacks down-dip water
- Up-dip water saturation
- Low porosity and permeability reservoirs
- Enhanced by fracturing and partings
Source Rocks

- TOC
- RockEval Pyrolysis (heating to 550°C)
  - S1 (volatile hydrocarbons)
  - S2 (pyrolytic hydrocarbons generated from pyrolysis)
  - S3 (CO2 generated from kerogen pyrolysis)
  - PI = (S2+S3)/TOC
  - Tmax = temperature at which maximum evolution of S2 hydrocarbons occurs

Well logs
- Density log: TOC
- Resistivity log: Maturity

Depositional Setting:
Lower and Upper Bakken Black Mudstone

Bakken Exploration History in US Williston basin.

Log suite, BN 9-27, Richland Co., MT (Cramer, 1991)
Note mud log shows in Middle Bakken.

Em Coulee Data

Kelly/Prospector
(Energyplus Resources)
Abras Fls 2-33
Sec. 53-24H-7NE
Plt: 10.451-468
IP: 73 (RFDP)
Flowed 2,191 barrels oil in the first 30 days beginning March 20, 1996
Treatment:
Water sand frac with 80,260 gallons water & 1,051,820 lbs sand
Cured: 1/sm:
52, 109 BCU, 65,567 MCF, 10,671 BBU

Middle Bakken Reservoir Data

- Formation type: Fractured sandstone, dolomite
- Vertical Depth: 3,500 to 10,000 ft
- Permeability: 10 to 20 md
- Porosity: 10 to 20%
- Oil saturation: 10 to 25 mg/cc
- Spacing Unit: Primary spacing 100 acres
- Reservoir Type: Fluvial sand bodies, delta front sand bodies
- Oil Gravity: 40 to 30° API
- Bottom Water: None
- GOR: 165,320 SCF/MMBTU
- Oil in Place: 270 B/MMBTU
- Primary Recovery Factor: 10 to 30%
- Recovery Factor: 20 to 35%
- Mineralogy: 7%

Well Spacing Units & Patterns

1280s
640s

From Findley, 2006
Core permeability, porosity, oil and water saturation, Vaira 44-24, Richland County, MT

Vaira - 10011

Core description of the Bakken 44-24 Vaira

Bakken Type Log

Upper Bakken Shale
Middle Bakken Shale
Lower Bakken Shale

Poisson's ratio vs depth, Sorensen #8-17 (Cramer, 1991)

Elbeouf Summary

Core permeability, porosity, oil and water saturation, Vaira 44-24, Richland County, MT

Primary Keys to Success of the Middle Bakken Play

- Horizontal Drilling & Completion of the Well with Fracture Stimulation
- Wells Contain 4,000' to 20,000' of Lateral per Well
- Typical Horizontal Fracture Stimulation
  ($115,000 to $250,000)
- Per Lateral (no open hole or unperforated perforated hole):
  - Drilled water sand free in general area
  - Sand concentrations from 5 to 40 pounds of sand per gallon
    (20-40 mesh sand, to 100 mps of hole)
  - Pumped at rate of 75 to 160 BPM, in 0 to 0.030' lateral. Total of
    5,000 lbs perft water and 400,000 m3 sand

Walker, 2006

Poisson's ratio vs depth, Sorensen #8-17 (Cramer, 1991)