

# **PS Role of Natural Fracturing in Production from the Bakken Formation, Williston Basin, North Dakota\***

**Stephen D. Sturm<sup>1</sup> and Ernest Gomez<sup>1</sup>**

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## **Abstract**

The Mississippian - Devonian Bakken Formation is a restricted - shallow water mixed carbonate – clastic sequence deposited over most of the Williston Basin. It consists of three members; Lower (dark marine shale with a high organic content), Middle (mixed carbonates and clastics) and Upper (dark marine shale with a high organic content). The Middle Member is the main reservoir unit, although in North Dakota it is characterized by low porosities (<8%) and permeabilities (<0.1 mD). Bakken production was first established from the Middle Bakken in the 1950s at Antelope Field, a fault bounded anticline located at the south end of the Nesson Anticline. The high initial rates and cumulative production in this field are attributed to natural fractures. Production also occurs in fractured shales of the Upper and Lower members southwest of the Nesson Anticline. These lines of evidence along with recent rates in excess of 2,000 BOPD in areas of low matrix properties have lead many to conclude that natural fractures are playing an important role in enhancing production from the Bakken. Recently released cores and image log interpretations, however, indicate that the overall fracture intensity and apertures are too small to adequately explain these high production rates. Other factors such as high pore pressure and lithology may actually be more relevant.

# Role of Natural Fracturing in Production from the Bakken Formation Williston Basin, North Dakota

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## Abstract

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# Bakken Research Consortium

## Objective

Provide an opportunity for industry leaders with governmental support to utilize the best available technologies to optimize understanding of the key factors associated with Bakken productivity – **“Science Project”**

## Location



## Participants

### Working Interest Partners

- XTO
- Continental
- Hess
- Brigham
- Encore
- Petro-Hunt
- Whiting

### Primary Technical Partner

- Schlumberger

### Secondary Technical Partners

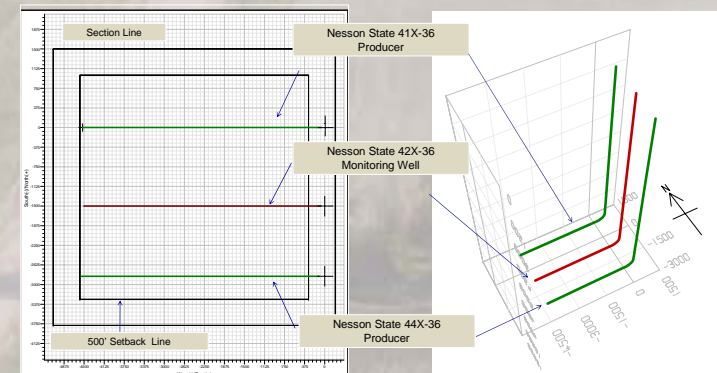
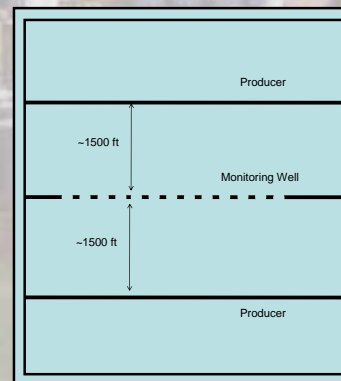
- Schlumberger/Terrascience
- MicroSeismic Inc
- United States Department of Energy (DOE)

### Grant Assistance

- North Dakota Oil and Gas Research Council

## Development Concept

- Drill three (3), 4000', single lateral wells close enough together to allow horizontal microseismic monitoring from the middle well
- Acquire complete set of modern logging suites in the laterals including the Formation MicroImager\* (FMI) for fracture characterization



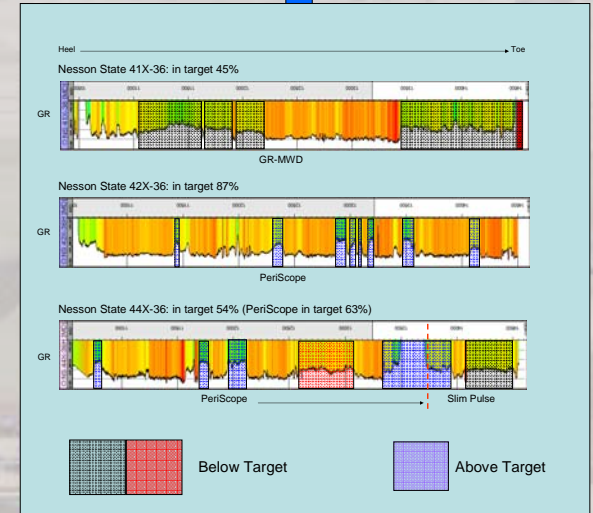
# Objectives and Scope

- Identify best available technologies to optimize geologic, drilling and completion practices associated with Bakken Productivity
- Reduce risk, create or add asset value
- Better understand the relationship between matrix and natural fractures with regard to reservoir performance
- Characterize natural fracturing:
  - lithological component
  - fracture height
  - fracture orientation
  - fracture aperture
  - relationship to mud gas logs
- Compare these findings with completion practices and production to determine effective methods to improve recovery

# Workflow Strategy

Drill 3 short lateral wells 1500' apart  
Using advanced drilling technologies

Target 'Clean GR Zone' in Middle Bakken



Evaluate Reservoir in Horizontals with:

- FMI\*
- Sonic Scanner\*
- ECS\*
- RST\*

Utilize 42X-36 well as Monitoring Well  
• 16 shuttles/1600' geophones

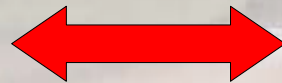
Complete 41X-36H with Pre-perforated liner

Complete 44X-36H with 8 swell packers  
• Placement based on reservoir evaluation



## Middle Bakken Reservoir

- Lateral Placement (Target Zone)
- ROP vs Cost
- Completion Practices
  - Slotted Liner
  - Open Hole



- Lithofacies
- Matrix Quality
- Phi, K
- Pore Pressure
- Rock Properties
- Poisson's Ratio
- Young's Modulus
- Natural Fracturing

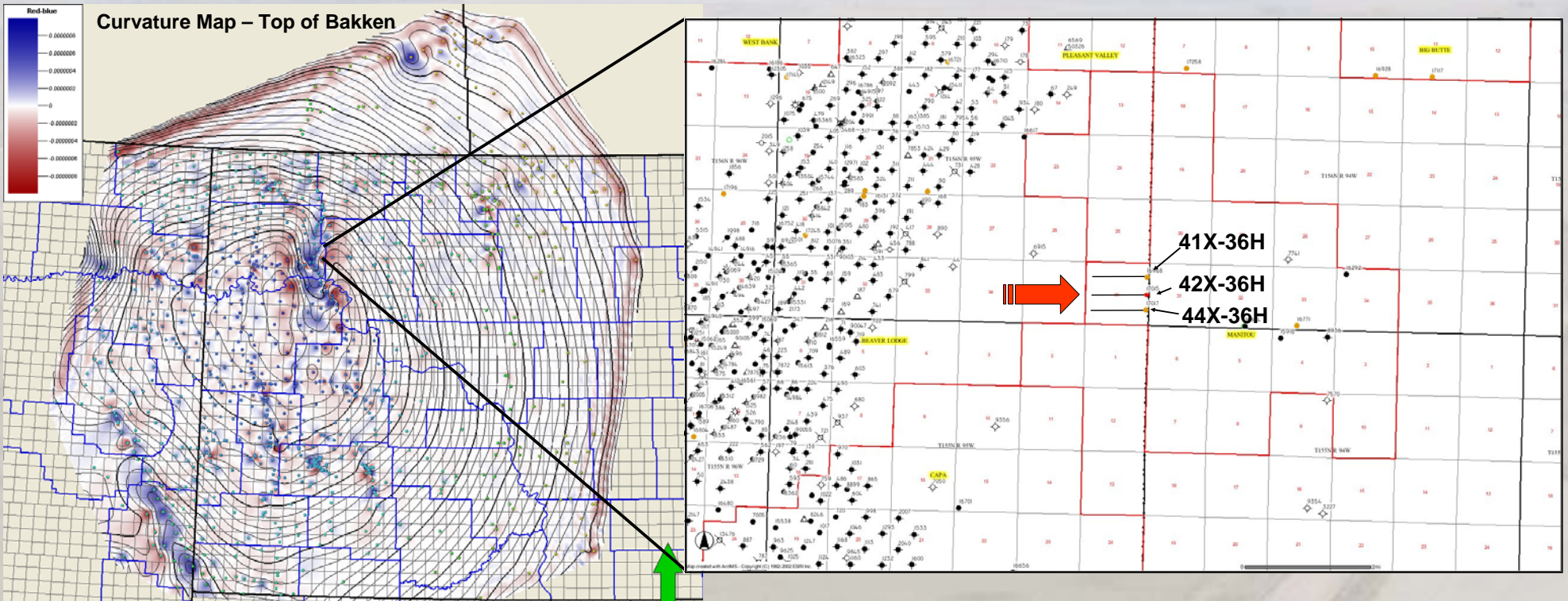
### Stimulation Design

- Perforations
  - SPF
  - Hole Diameter
- Fluid type
- Proppant type
- Bridging material



\* Mark of Schlumberger

# Bakken Research Consortium Study Area



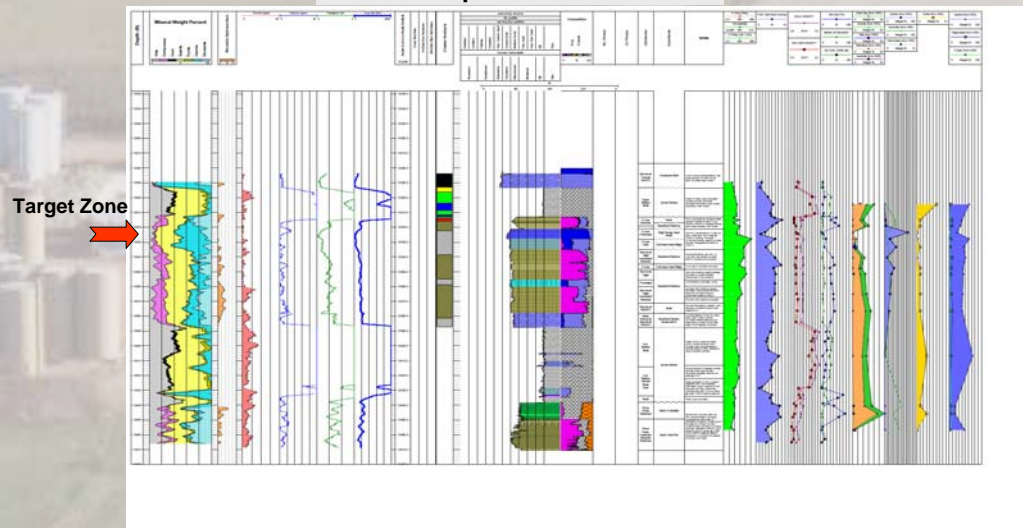
## Background Information

*New geologic models applied to the Bakken Formation, advances in drilling and production technologies, and recent oil discoveries have resulted in these substantially larger technically recoverable oil volumes. About 105 million barrels of oil were produced from the Bakken Formation by the end of 2007 (USGS, 2008).*

The Bakken Consortium Study area is located approx. 4 miles east of the Beaver Lodge Field (Nesson Anticline) in Williams County, North Dakota (Sec 36. –T156N –R95W).. The Manitou field area is located off the east flank if the Nesson Anticline is located in an area of minor structural curvature, and has monoclin dip of <math><1.5^\circ</math>. **Compared to other areas of the Williston Basin, this area appears to have a higher potential for natural fracturing due to structural influence.**

Formation MicroImager (FMI) logs were acquired in each lateral to characterize fracture attributes. Lateral wells targeted the high carbonate sequence, or 'clean-zone' approximately 8' below the base of the U. Bakken Shale. Because the wells (negatively or positively) exited the target zone along the lateral length, fracture statistics related to lithology (or facies) were then calculated for the Middle Bakken.

## Core Description – 42X Pilot Hole



# Middle Bakken Fracture Characterization

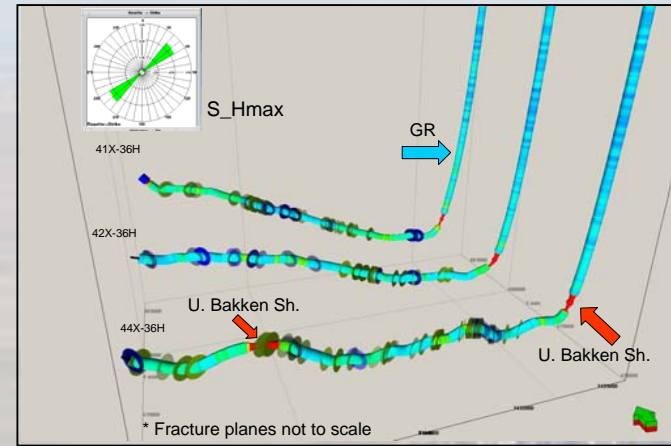
Formation MicroImager (FMI) logs were acquired on the 3 lateral wells to identify and characterize fracturing. Analysis of borehole image data indicates that both Natural and Induced Fracturing does occur within the Middle Bakken.

## NATURAL FRACTURES

- **Are rare**, and occur mostly in the low-GR, high CaCO<sub>3</sub> 'parasequence', or the "clean-zone"
- Natural Fractures are mostly in the **NW-SE orientation**, or in the S<sub>H</sub>min orientation
- Natural Fractures are 'bed-bound', with fracture height <2 ft.
- Natural fractures have dips ranging from 70 – 90°
- All Natural Fractures have resistive cement along fracture faces
- Natural fractures have microdarcy to nannodarcy permeability
- Cum fracture porosity ranges from 0.0003 – 0.0005%
- No Correlation to Mud Gas

## INDUCED FRACTURES

- Occur mostly in higher stress [Young's Modulus – Poisson's Ratio] lithologies
- Are discontinuous, and have higher aperture on TOP and BOTTOM of borehole
- Do Not exhibit any resistive cement along fracture face
- Have >80° fracture dip
- Define S<sub>H</sub>max at N 45-55°E



# FMI Fracture Interpretation

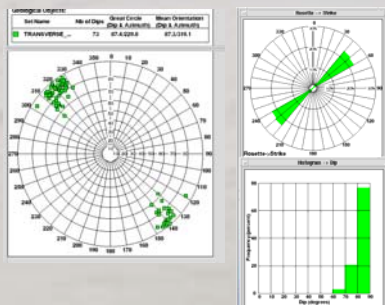
41X-36H

42X-36H

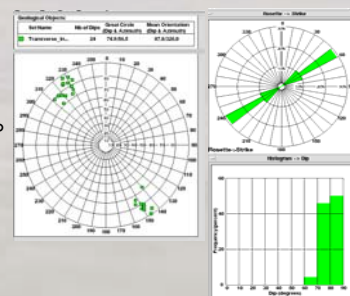
44X-36H

## Stress

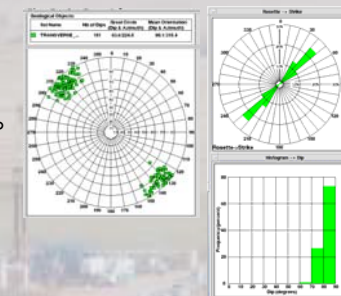
S\_Hmax = 49°



S\_Hmax = 56°



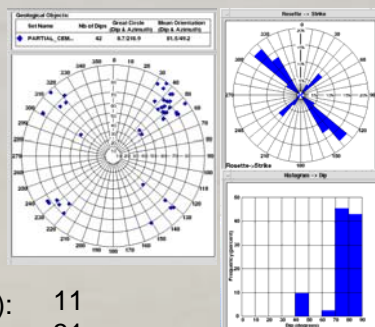
S\_Hmax = 45°



## Natural Fractures

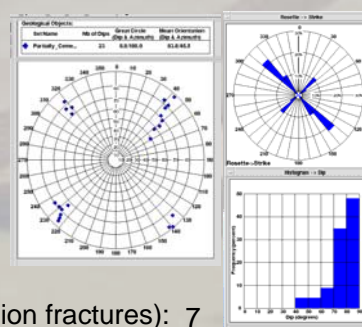
N = 42

# NE-SW (extension fractures): 11  
# NW-SE fractures: 31



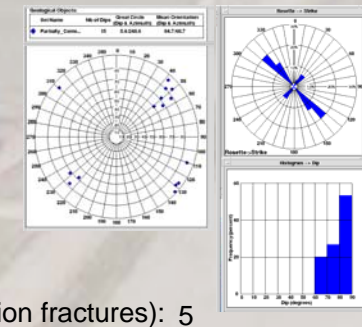
N = 23

# NE-SW (extension fractures): 7  
# NW-SE fractures: 16

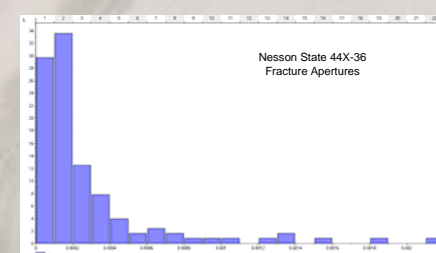
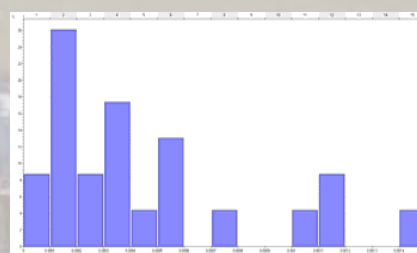
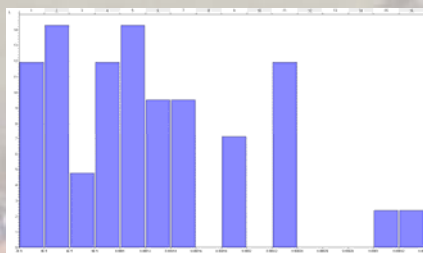


N = 15

# NE-SW (extension fractures): 5  
# NW-SE fractures: 10



## Fracture Aperture

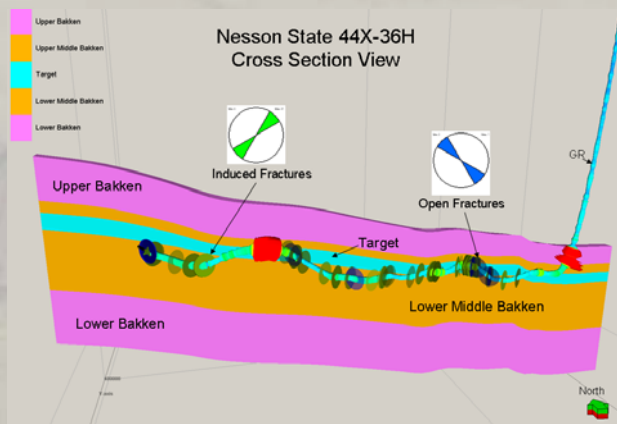
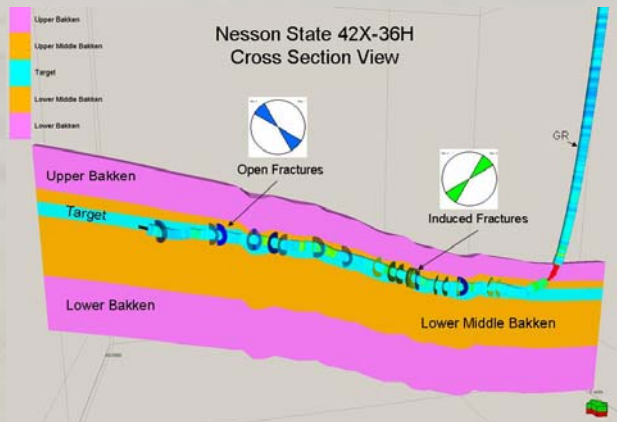
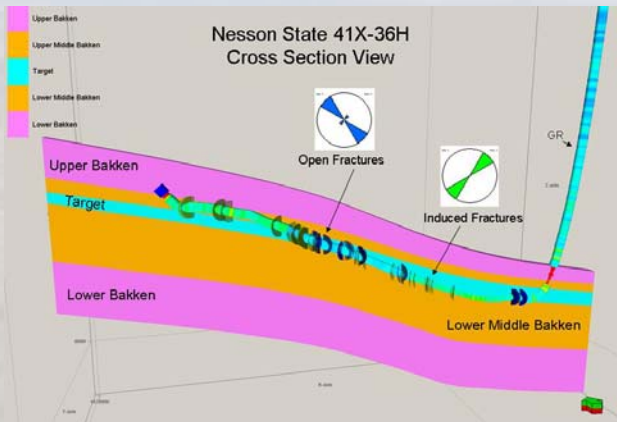


Lateral Length (ft)	3643
Natural Spacing (ft) (Wellbore Length)	87.2
Natural Spacing (ft) (Target Zone)	39.0
Net Fracture Phi	0.0003%

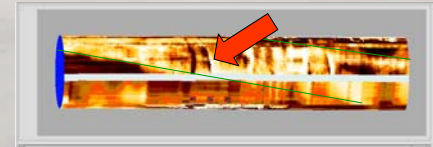
Lateral Length (ft)	3751	3987
Natural Spacing (ft) (Wellbore Length)	163.1	265.8
Natural Spacing (ft) (Target Zone)	141.9	143.5
Net Fracture Phi	0.0005%	0.0004%

# Results and Conclusions

## Natural Fracturing in Middle Bakken



- Low-frequency fracturing is present in the Middle Bakken interval
  - Fractures occur predominantly in the high CaCO<sub>3</sub> ‘parasequence’ in the upper Middle Bakken
  - Fractures are bed-bound, limited to the height of thin-beds (~2’)
  - Vertical fracture connectivity is poor



- Fracture spacing (between fractures) is variable;
  - From 39’ ⇔ 144’ in “target-zone”
  - From 87’ ⇔ 266’ along lateral length
  - Fractures are relatively non-existent in the lower Middle Bakken dolomitic rocks
    - Laterals placed in this zone will drill faster, and not encounter natural fractures

- Fracture orientation is bi-modal in the Consortium wells
  - NW-SE striking fractures are dominant
  - NE-SW striking extension fractures in-line with S<sub>H</sub>max are subordinate

- Fracture planes dip in opposed directions from 60° ⇔ 90° (mean > 80°)

- Fractures are partially-filled with carbonate cement
  - Fracture aperture is in the nannodarcy range
  - Cumulative fracture porosity is 0.0003 ⇔ 0.0005%

- There is **NO CORRELATION** of FRACTURES TO MUD GAS
  - Increase in mud gas is typically observed at the toe of the laterals

