# POTENTIAL FOR CO. UTILIZATION AND STORAGE IN THE BAKKEN FORMATION



Putting Research into Practice

THE UNIVERSITY OF NORTH DAKOTA

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### Introduction

In recent years, exploration and development of oil and gas resources have increased in tight, shale-dominated formations. One of the largest of these tight oil resources is the Bakken petroleum system in the Williston Basin of the United States and Canada. However, primary oil recovery rates are low, typically less than 10% of the estimated original oil in place. As efforts are made to improve the recovery factors of these unconventional reservoirs, many companies are considering the use of carbon dioxide (CO<sub>2</sub>) for enhanced oil recovery (EOR). Laboratory experiments using Bakken rocks and fluids, evaluation of reservoir characterization data from Bakken wells, and geomodeling activities for selected Bakken reservoirs were conducted to understand the potential magnitude of CO<sub>2</sub> utilization and storage in tight oil formations.

Additionally, detailed geologic field models focusing on the Middle and Lower Members of the Bakken Formation in two different areas of North Dakota were developed. Several injection/production scenarios were simulated. Because naturally occurring micro- and macrofractures can provide major connective paths to the matrix pores, injection wells should be placed in areas known to have high natural fracture intensity. Such fracture "swarm" areas will provide ample surface areas for CO<sub>2</sub> penetration into the matrix. Generally speaking, the results of these activities suggest that tight oil formations may serve as targets for the geologic storage of CO<sub>2</sub> and that the injection of CO<sub>2</sub> may be effective in enhancing oil production from tight oil formations.

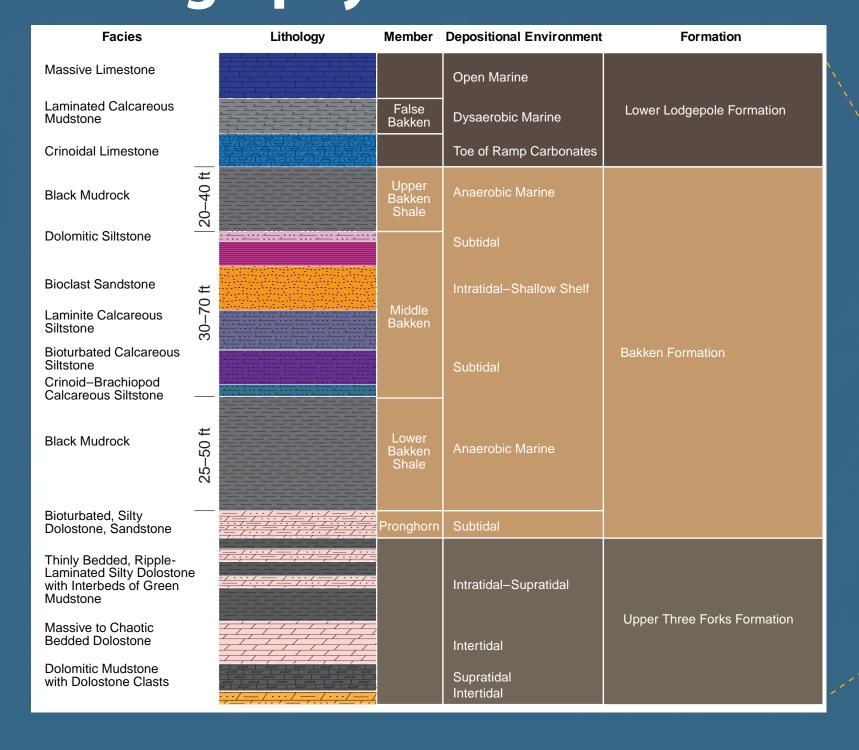
## The Bakken Oil Play

Largest tight oil formation in North America, both in terms of geographic extent and oil resource.

- · Productive area includes parts of North Dakota, Montana, Saskatchewan, and Manitoba.
- The Bakken petroleum system includes several distinctive zones within two different rock formations:
- Bakken Formation Three Forks Formation



### **Stratigraphy**



#### Production

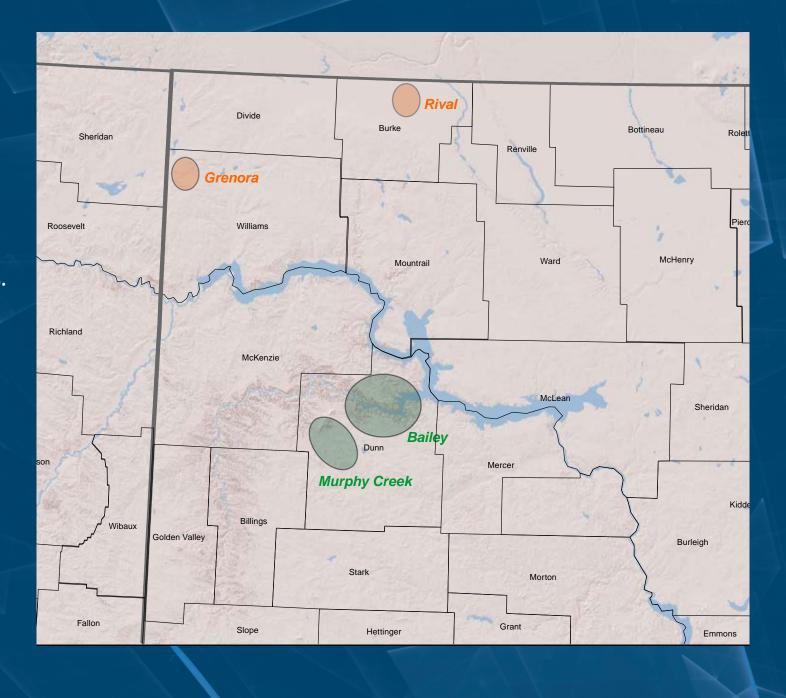
- Bakken–Three Forks Production (July 2014) • Over 10,000 wells in North Dakota
- Over 1,000,000 bbl/day of oil
- Over 1 Bcf/day of gas
- Horizontal wells and hydraulic fracturing
- How much bigger can Bakken get?
- Currently, only a 3%–10% recovery factor.
- Small improvements in recovery could yield over a billion barrels of oil.
- Could CO<sub>3</sub> be a game changer in the Bakken?

# 66Over 1,000,000 bbl/day of oil ??

# Project **Study Fields**

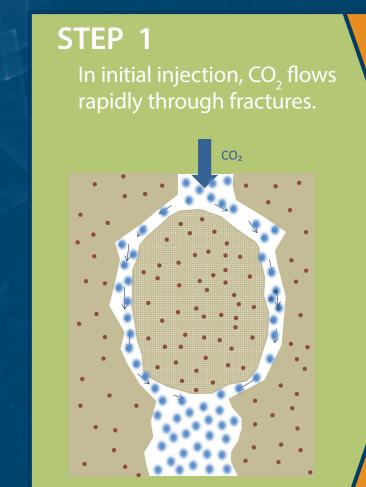
Compare thermally mature to immature:

- Characterize core from Bailey and Murphy Creek (mature) vs. Rival and Grenora (immature). • Perform static and dynamic
- modeling of the Bailey and



#### **Mechanisms of Interaction**

The conceptual mechanisms for CO<sub>2</sub> EOR in tight, hydraulically fractured systems.

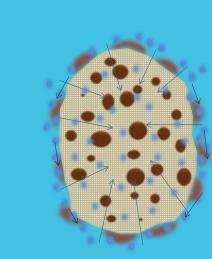


STEP 2 CO<sub>3</sub> starts to permeate rock based on pressure gradient.

CO<sub>2</sub> moves oil into the rock.

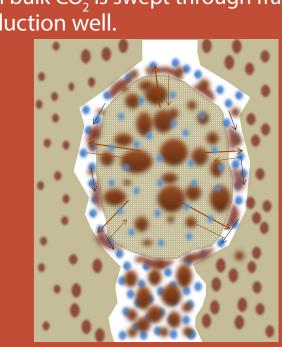
#### STEP 3 As CO<sub>3</sub> permeates into the

rock, oil migrates to bulk CO<sub>2</sub> in fractures based on swelling and lower viscosity.



STEP 4 CO<sub>2</sub> pressures equalize inside of rock.

• Oil production is now based only on concentration gradient-driven diffusion. • Oil in bulk CO<sub>3</sub> is swept through fractures to production well.



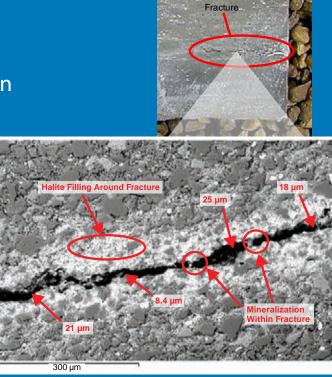
### **Reservoir Evaluation Methodology**

#### Laboratory **Techniques**

- Optical microscopy • X-ray fluorescence
- spectroscopy X-ray diffraction
- Energy-dispersive x-ray spectroscopy
- Quantitative elemental analysis and mineral determination
- Scanning electron microscopy (SEM)
- High-magnification backscatter electron image analysis Helium gas porosimeter

#### **Analysis of Fractures**

- Analysis of Macrofractures Fracture properties
- Aperture, length, and orientation measured
- Microfractures Studied by SEM
- Identified microfractures:
- Open vs. closed • Fracture properties:
- Aperture and length measured
- Macrofracture and microfracture
- data are used to help populate fracture properties in the static geologic model.



#### **Analysis of Matrix**

- All four areas had significant amounts of naturally occurring fractures.
- Microfractures accounted for most of the porosity in the most productive
- Macrofracture and microfracture data are essential to creating

#### Static Geomodeling

- Structural model Matrix petrophysical model using
- multimineral petrophysical analysis • Fracture petrophysical zones of the Bakken. model
- Dual-porosity-dualpermeability model • Predictive numerical realistic geologic models.

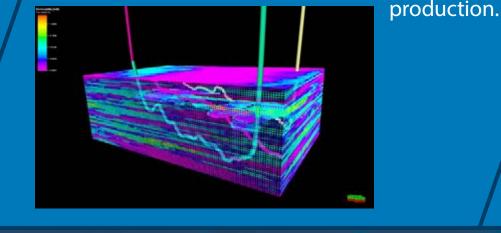
#### **Simulation Modeling**

• Huff 'n' puff (HnP)

pushes oil out

of the rock

- Injector and producer pairs
- Nine different scenarios
- HnP showed little to no incremental oil production. Injector–producer pairs appear to be most promising. Best cases showed 40% to 50% improvement in oil



#### **Hydrocarbon Elution Experiments**

- Laboratory results indicate that CO<sub>3</sub> can effectively extract hydrocarbons (HCs) from both Middle and Lower Bakken rock matrix:
- Over 90% from Middle Bakken.\*
- Over 60% from Lower Bakken shale.\* Primary
- mechanism is likely
- diffusion.

# Bakken CO, EOR and Storage Capacity Potential

The U.S. Department of Energy (DOE) methodology for estimating CO<sub>3</sub> EOR and storage capacity (Carbon Sequestration Atlas of the United States and Canada, 2007) was applied to the Bakken:

• Preliminary estimate suggests that the demand to fully apply EOR in the Bakken is 2 to 3.2 billion tons of CO<sub>2</sub>.

• This would yield 4 to 7 billion barrels of incremental oil.

# **Next Steps – Phase II Research**

The primary goal Is to conduct a pilot injection test in the field • Current industry partners include Continental Resources, Marathon Oil, Kinder-Morgan, Computer Modelling Group Ltd., and Baker Hughes.

Select potential injection and production schemes.

– Number and spacing of injectors and producers? – Inject into the Middle Bakken or the shales?

• Improve our understanding of oil/CO<sub>2</sub>/natural gas phase behavior under various reservoir conditions at partner locations.

• Further improve reservoir characterization.

- Microfracture characterization. – Hydrocarbon extraction data on key Bakken and Three Forks lithofacies at partner locations.

– Integration of improved data into more sophisticated models.

### **Key Initial Findings**

modeling

 Initial estimates suggest that the Bakken Formation in North Dakota may have a CO<sub>3</sub> storage resource as high as 3.2 Gt. However, more data are required to accurately assess the CO<sub>2</sub> storage potential in tight oil-bearing formations such as the Bakken.

 Dynamic simulation modeling of the Bailey area in Dunn County suggests that the injection of CO<sub>2</sub> could increase oil production by as much as 50%. Results also indicate that a scheme that pairs two injection wells with a single production well is the most effective approach. Simulation results also indicate that diffusion plays a significant role in moving oil from the reservoir matrix into the fracture network.

• Laboratory experimental studies indicate that CO, can remove over 90% of HCs from Bakken reservoir rocks and up to 60% from the shales in a time frame that ranges from hours to days in small-scale elution experiments. Diffusion appears to be the primary mechanism driving the observed HC removal.

 In the Bakken, CO<sub>2</sub> flow will be dominated by fracture flow and not significantly through the rock matrix. Fracture-dominated CO<sub>2</sub> flow could essentially eliminate the displacement mechanisms responsible for increased recovery in conventional reservoirs. As such, other mechanisms, such as diffusion, must be optimized in tight reservoirs.











This material is based on work supported by the U.S. Department of Energy (DOE) National Energy Technology Laboratory under Award No. DE-FC26-08NT43291.