

# ***The EERC's CO<sub>2</sub> Enhanced Bakken Recovery Research Program***

**NDIC - OGRC  
January, 2013**

**John Harju**

## **Project Sponsors**

**U.S. Department of Energy – National Energy Technology Laboratory  
North Dakota Industrial Commission – Oil & Gas Research Council  
Marathon Oil Corporation  
TAQA North Ltd.**

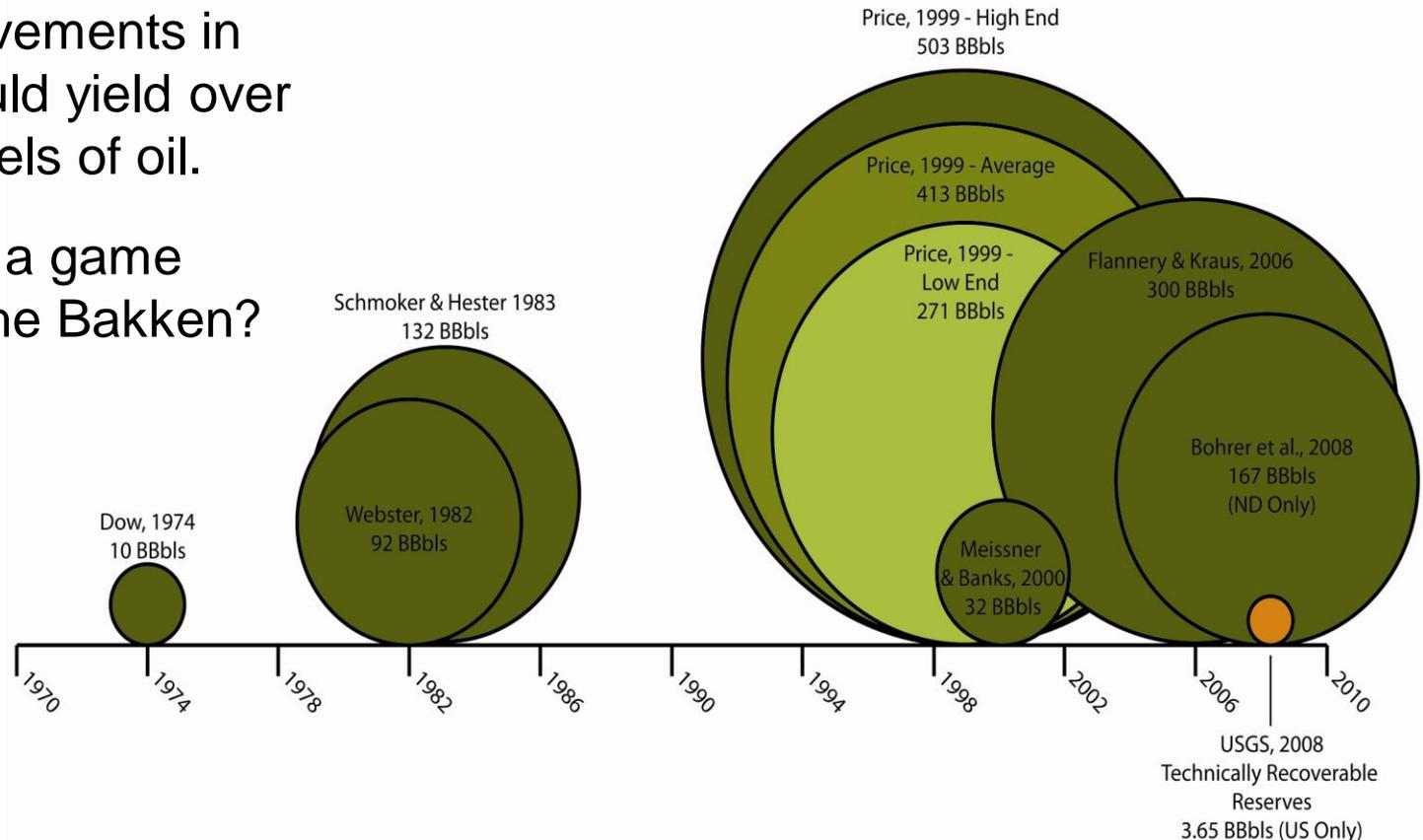


**Energy & Environmental Research Center (EERC)...**  
The International Center for Applied Energy Technology®

# How Much Bigger Can Bakken Get?

- Currently, only 3%– 10% recovery factor.
- Small improvements in recovery could yield over a billion barrels of oil.
- Can CO<sub>2</sub> be a game changer in the Bakken?

Bakken Total Oil in Place Reserve Estimates

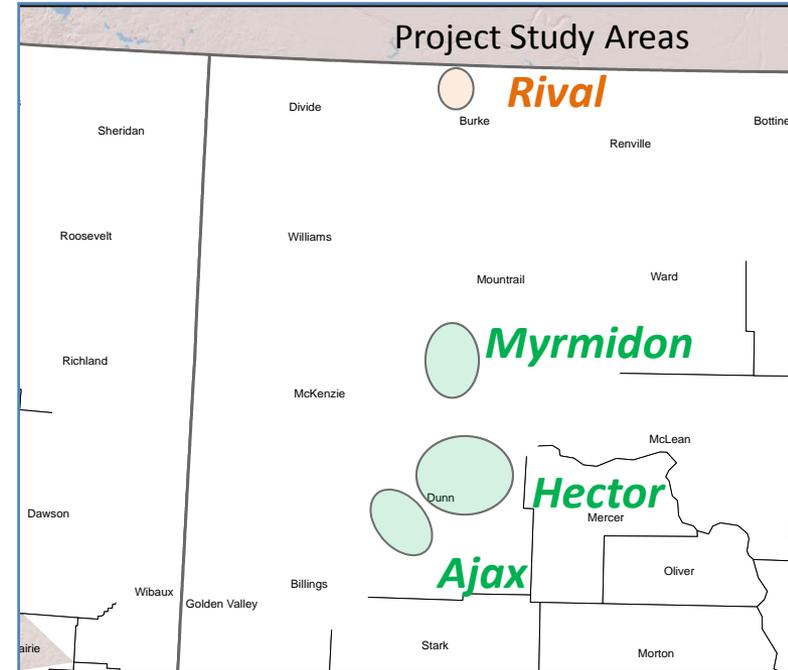


# CO<sub>2</sub> Enhanced Bakken Recovery Research Program in a Nutshell

- Laboratory- and modeling-based examination of the potential use of CO<sub>2</sub> for enhanced oil recovery (EOR) in the Bakken Formation.
- Total cash contributions to the project: \$1,375,000
- Contributing partners:
  - DOE-NETL (\$450,000 cash)
  - NDIC-OGRC (\$475,000 cash)
  - TAQA North, Ltd. (\$150,000 cash + in-kind)
  - Marathon Oil Company (\$50,000 cash + in-kind)
- Project duration: 17 months
- Project initiated in June 2012

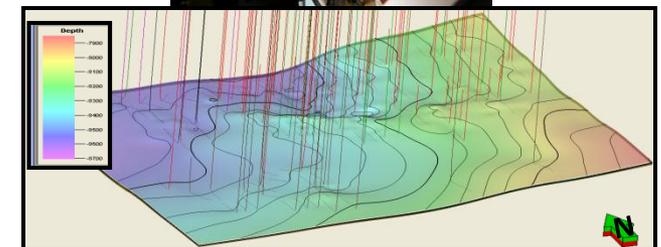
# Where Are We Going with This?

- Previous attempts using “conventional” CO<sub>2</sub> huff ‘n’ puff for EOR in the Bakken have met with marginal success.
- The ultimate goals of this program are to use the insight developed by our research to:
  - Design a viable implementation approach for CO<sub>2</sub>-based EOR.
  - Improve our understanding of the potential for tight oil formations to store CO<sub>2</sub>.
- The end game is to be involved with at least one of our partners in a follow-on field test within 2 years.



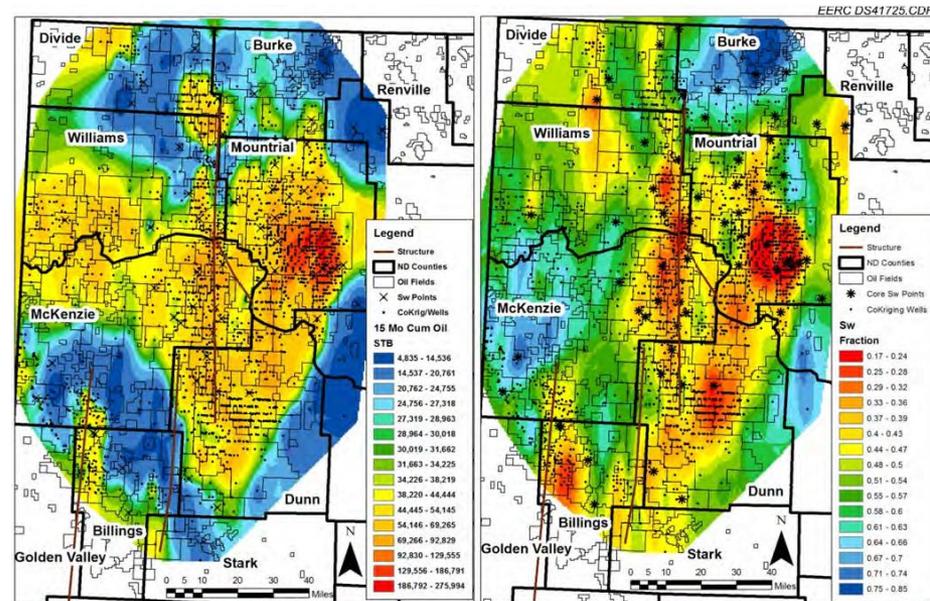
# Project Approach

- The goal is to predict the performance of CO<sub>2</sub> EOR in the Bakken based on lab experiments coupled with modeling.
  - Quantify phase behavior and fluid properties under reservoir conditions.
  - Data from three Bakken pools will be used to compare different types of Bakken reservoirs.
  - Lab analyses include:
    - ◆ Detailed analyses of Bakken reservoir rocks.
    - ◆ Determination of key Bakken oil properties relative to CO<sub>2</sub>.
  - Modeling will integrate well file data and experimentally derived data to:
    - ◆ Generate geologic reservoir models.
    - ◆ Conduct dynamic simulation modeling.



# Approach – Task 1

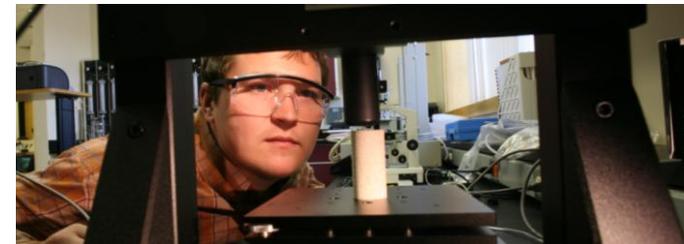
- Task 1 – Detailed Characterization of Selected Bakken Fields
  - Previous work has identified relationships between reservoir properties and productivity.
  - Relationship between water saturation and production may help identify areas amenable to CO<sub>2</sub> EOR.
  - Reservoir fluid and rock properties for a given location are crucial to predict EOR effectiveness.
  - Minimum of three Bakken study pools:
    - ◆ Thermally immature, structurally controlled reservoirs in northern-tier counties.
    - ◆ Thermally mature reservoirs in basin center.



15-month cumulative oil production (left) compared to water saturation (right).

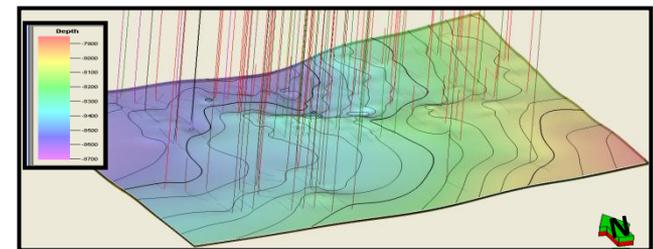
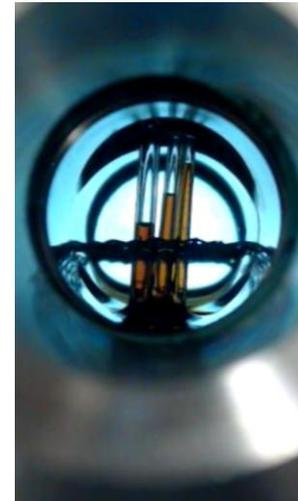
# Task 1 Activities Have Been Initiated

- Core-Based Lithofacies and Fracture Studies
  - Results in detailed measurements and descriptions of macroscopic attributes and classification of lithofacies
- Core-Based Petrographic Studies
  - Thin sections, x-ray diffraction [XRD], scanning electron microscopy [SEM]
  - Result in detailed descriptions of key rock properties
- Comparison of Core to Well Log Data
  - Results in correlation of log responses to key rock attributes
- Fracture Analysis
  - Results in data to support development of discrete fracture network which is integrated into base static models.
- Static geologic model development
  - Results in isopach maps, cross sections, and 3-D models



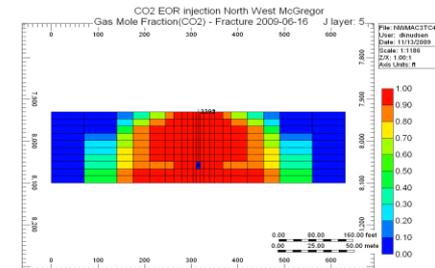
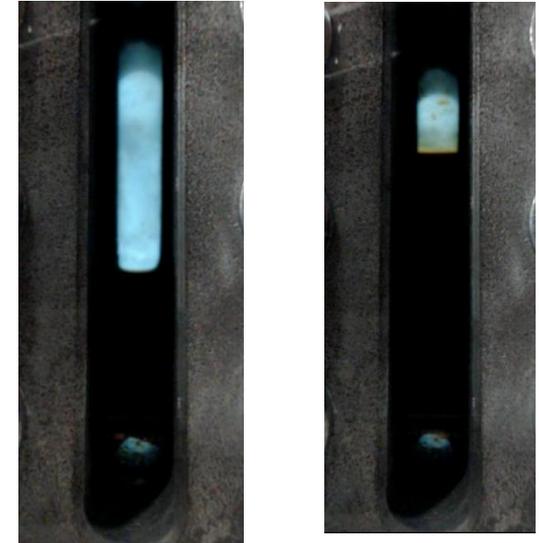
# Approach – Task 2

- Task 2 – Examination of the Use of CO<sub>2</sub> for EOR in the Bakken
  - Challenges to EOR within the Bakken
    - ◆ Mobility of “traditional” EOR fluids through fractures relative to very low matrix permeability.
    - ◆ The aversion of exposing swelling clays to water.
    - ◆ Oil-wet nature of much of the North Dakota Bakken will minimize effectiveness of water flooding.
    - ◆ These issues suggest CO<sub>2</sub> may be effective.
  - Experimental data and modeling will be used to predict performance of CO<sub>2</sub> for EOR in the Bakken.
    - ◆ Quantify phase behavior and fluid properties under reservoir conditions.
  - Integrate lab data with static models to conduct dynamic simulation modeling for at least two Bakken reservoirs.
    - ◆ Static model will be at the drilling spacing unit scale (160 acres).



# Task 2 Activities Have Been Initiated

- Acquisition of reservoir fluids
  - Crude oil samples from the selected study pools for use in experimental and analytical activities.
- Laboratory determination of key Bakken oil properties relevant to CO<sub>2</sub>-based EOR
  - Standard fluid properties
    - ◆ Formation volume factor for gas and oil
    - ◆ Viscosity for gas and oil
    - ◆ Solution gas-to-oil ratio (GOR)
  - Oil composition
  - API gravity
  - Thermodynamic minimum miscibility pressure (MMP)
  - Crude oil swelling
  - Crude oil viscosity reduction
  - Single- and multiple-contact phase volumes
- Dynamic modeling
  - Phase equilibrium modeling of the reservoir fluid/CO<sub>2</sub> system under relevant conditions
  - Core scale simulations based on Task 1 and 2 data.



# Expected Results and Products

## Results

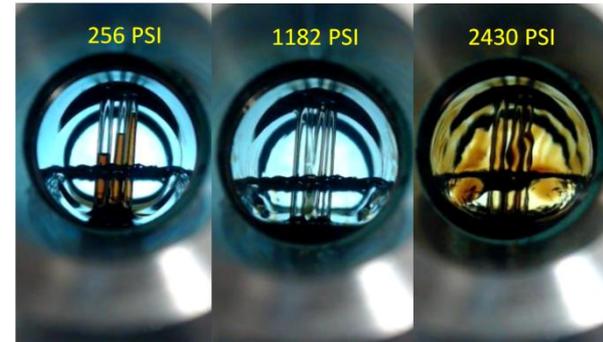
- Guidance for future laboratory and field activities.
- Previously unavailable insight regarding Bakken oil MMP.
- Previously unavailable insight regarding Bakken relative permeability to CO<sub>2</sub>.
- Insight into the potential use of CO<sub>2</sub> for EOR in the Bakken.
- Insight to the potential storage of CO<sub>2</sub> not only in the Bakken, but in tight oil formations in general.

## Products

- Quarterly reports summarizing progress, challenges, solutions to challenges, next steps.
- Final report presenting results, implications of results to the use of CO<sub>2</sub> for Bakken EOR, and recommendations for path forward.
- Reports and selected data sets made available on EERC Bakken Decision Support System.
- Posters and/or presentations at one to two technical conferences.

# Accomplishments to Date

- Partner-generated lab and field data (well logs, PVT studies, petrophysical studies, petrographic studies, etc.) have been compiled and continue to be provided
- Oil swelling and MMP testing have been conducted using fresh oil samples from partners.
- Core plug samples from Marathon fields in Dunn County have been collected.
- Fracture analysis of 2 cores from Dunn County have been completed.
- Creation of static model for Dunn County area has been initiated.



# Next Steps

- Petrophysical and petrographic analysis of Dunn County samples will be completed by March 15, 2013.
- Meet with Marathon technical team in March to ensure that the finalization of the EERC static model dovetails with Marathon's modeling efforts.
- Static model of Dunn County study area will be completed by end of May, 2013.
- Dynamic simulation modeling of Dunn County study area will be initiated in June, 2013 and completed by August, 2013.
- TAQA North has requested that focus be shifted from the Flat Lake field in Montana to the Rival field in Burke County, North Dakota.
- It is anticipated that work on Bakken core from Rival will run approximately one month behind the Dunn County work.

# Dissemination of Key Results Bakken Decision Support System Website

<http://www.undeerc.org/bakken/>



[About the EERC](#)

[Contact Us](#)

[Sponsors](#)

[Site Map](#)

[Home](#)

[Purchase a Bakken Map](#)



**Bakken Formation  
Geology**



**Completion  
and Stimulation**



**Current Research  
Studies**



**Resource Toolbox**



## Downloadable Resources

Obtain data regarding well locations, completion information, and production



## Decision Support

Find oil production and geologic data for the North Dakota portion of the Williston Basin



## Bakken News

- Economist: ND oil could save America (Williston Herald)

# Potential Impact to American Oil Production

## Technologic & Economic Impact to North Dakota

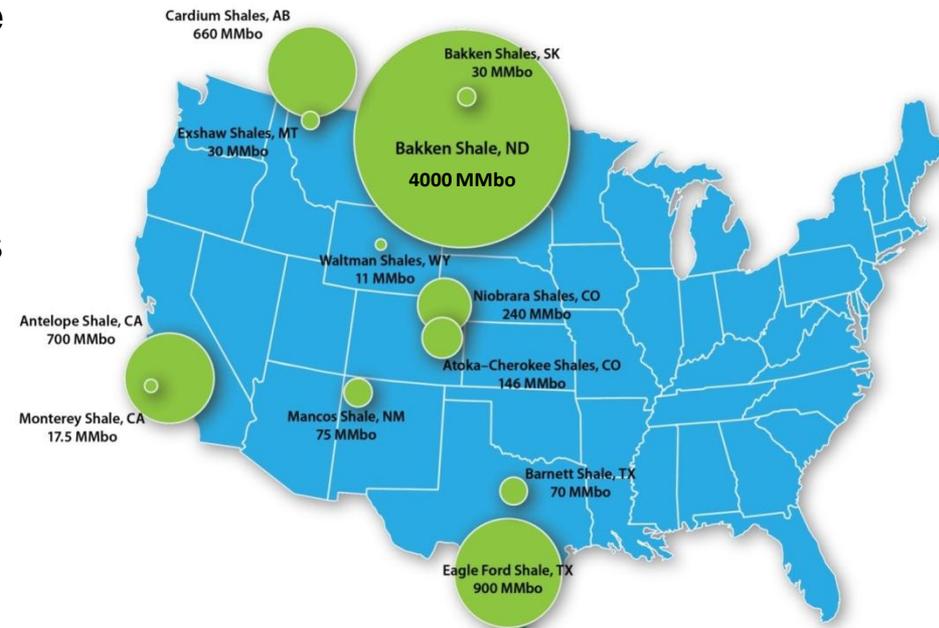
- ND Dept. of Mineral Resources estimates that OOIP for the Bakken and Three Forks combined in North Dakota is approximately 170 billion barrels (Bbbls).
- If the application of CO<sub>2</sub> for EOR can **improve recovery by just 1.1%**, that improvement would **translate to an additional 1.87 Bbbls** of oil production.
- Assuming an average **oil price of \$80/bbl**, this would equate to approximately **\$150 billion** worth of oil.
- Application of CO<sub>2</sub> EOR could also prolong the life of the Bakken oil fields by decades.
- Results may also be applicable to tight oil plays across the United States, yielding billions of barrels of oil.



# Ultimate Impact to North Dakota

## Technologic & Economic Impact

- ND Dept. of Mineral Resources estimates that OOIP for the Bakken and Three Forks combined in North Dakota is approximately 170 billion barrels (Bbbls).
- If the application of CO<sub>2</sub> for EOR can improve recovery by just 1.1%, that improvement would translate to an additional 1.87 Bbbls of oil production.
- Assuming an average oil price of \$80/bbl, this would equate to approximately \$150 billion worth of oil.
- CO<sub>2</sub> EOR could prolong the life of the Bakken oil fields by decades.
- Results may be applicable to tight oil plays across the United States in Texas, Montana, California, Mississippi, Ohio, etc.



# Contact Information

## **Energy & Environmental Research Center**

University of North Dakota

15 North 23rd Street, Stop 9018

Grand Forks, ND 58202-9018

World Wide Web: **[www.undeerc.org](http://www.undeerc.org)**

Telephone No. (701) 777-5157

Fax No. (701) 777-5181

**John Harju, Associate Director for Research**

**[jharju@undeerc.org](mailto:jharju@undeerc.org)**