



UNCONVENTIONAL RESERVOIR ENGINEERING PROJECT
Colorado School of Mines



GAS INJECTION EOR IN UNCONVENTIONAL LIQUID-RICH RESERVOIRS

LABORATORY EXPERIMENTS IN CORES

Asm Kamruzzaman

PhD Student

Petroleum Engineering Department

Colorado School of Mines



UNCONVENTIONAL RESERVOIR ENGINEERING PROJECT

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GAS INJECTION EOR IN LIQUID-RICH SHALE RESERVOIRS

AN EXECUTIVE SUMMARY

Great advancements in horizontal drilling and hydraulic fracturing technology have enabled oil industry to produce oil and gas commercially from unconventional shale reservoirs. Nonetheless, the cumulative oil production from **liquid-rich** unconventional **shale reservoirs** is around 6%. This production is mainly by **depletion drive** mechanism, and to date none of the classical **secondary or tertiary recovery** techniques has shown any promise for additional oil recovery with the exception of **wet gas injection**. Thus, there is a need to search for new ideas to increase the current level of oil recovery from shale to higher levels, say 10%, which is the main goal of this **research proposal**.

– Dr. Hossein Kazemi



OUTLINE

- Objectives of Gas Injection EOR Study
- Physics of Cyclic Gas Injection EOR
- Gas Injection EOR Laboratory Setup
- Specifics of Core Flooding Apparatus
- Laboratory Budget
- Needs and Timeline
- Concluding Remarks

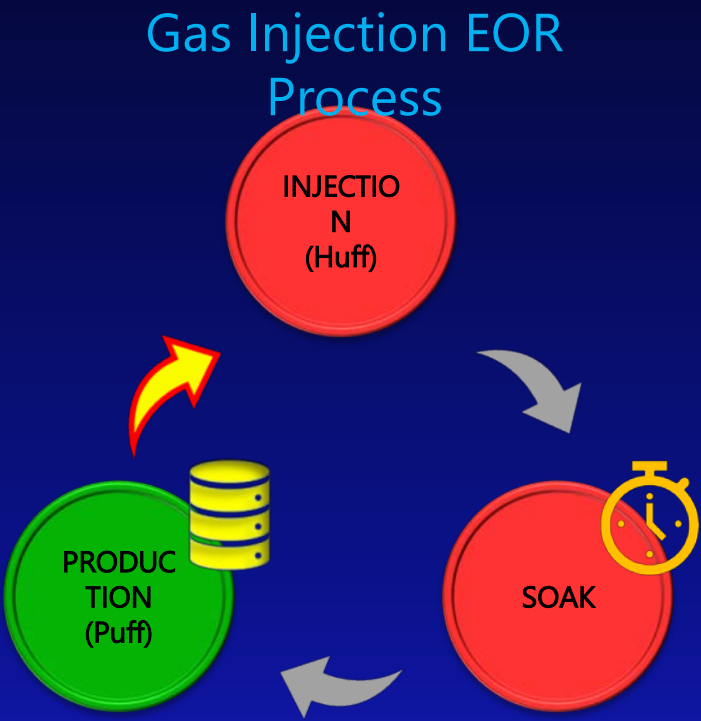
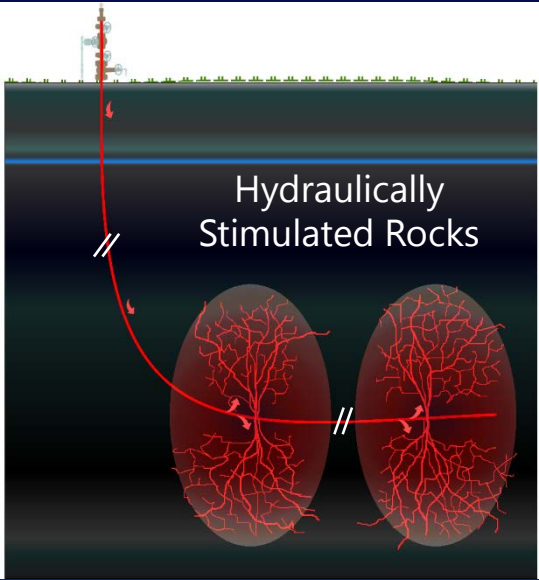


OBJECTIVES OF GAS INJECTION EOR STUDY

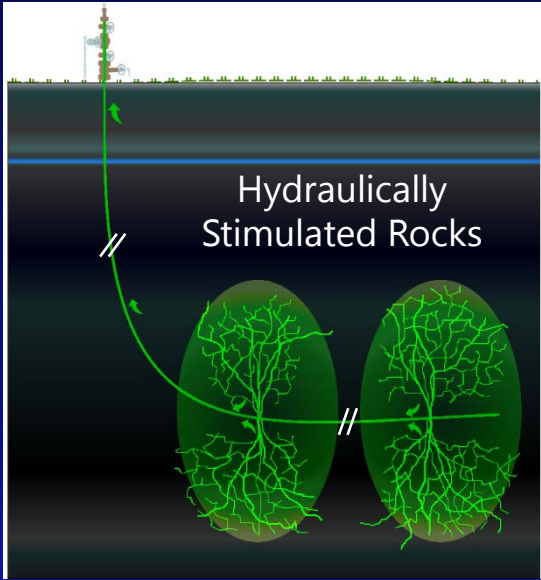
- **Build core flooding apparatus** to conduct gas injection EOR experiments.
- **Determine incremental oil recovery** in unconventional shale cores.
- **Use Ilkay Eker's** (PhD Thesis, CSM, 2018) in-house **reservoir model** to evaluate gas injection EOR, and **scale** laboratory results to **field**.
- **Explore industry interest** in conducting an EOR field pilot test.



Injection & Soak Period



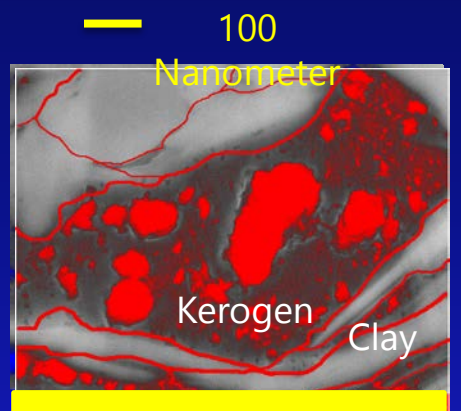
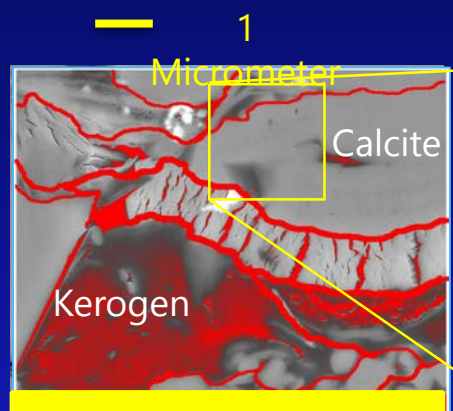
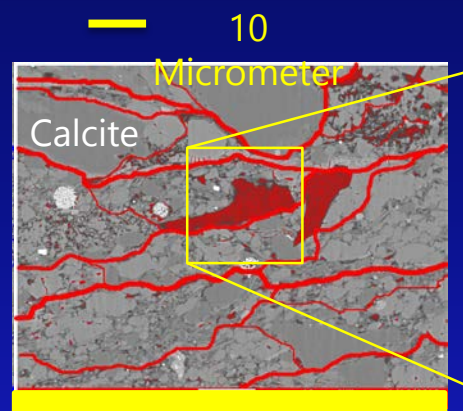
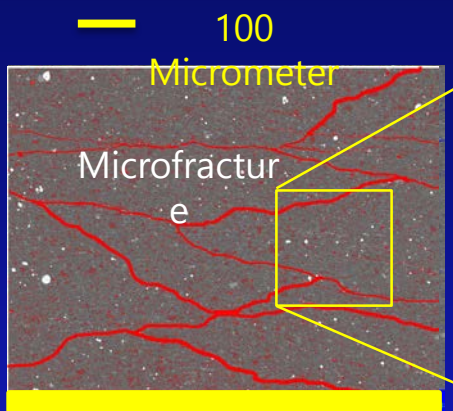
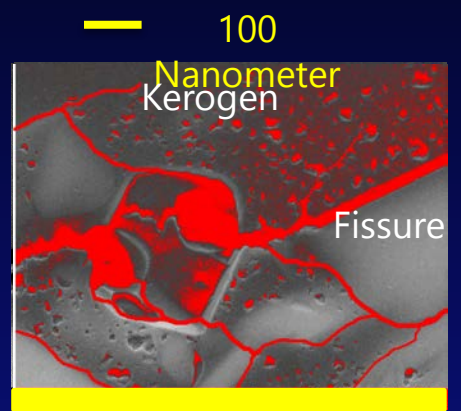
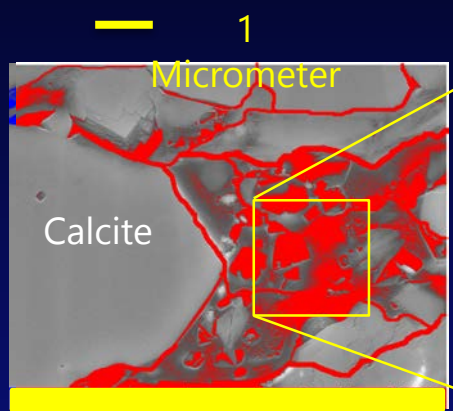
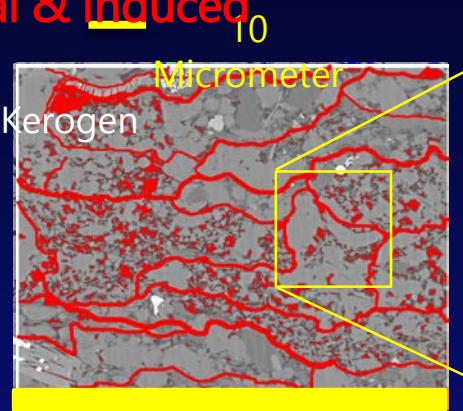
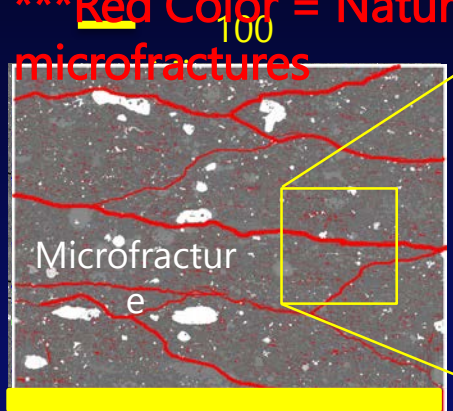
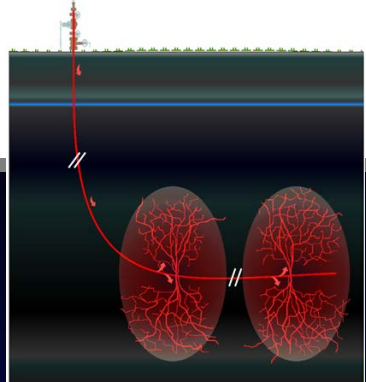
Production Period



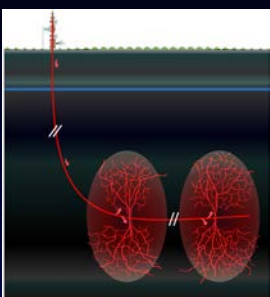
PHYSICS OF GAS INJECTION EOR (CONT.)

- *Note the Scale
- **Blue Color = Areas of effective/connected pores
- ***Red Color = Natural & induced microfractures

Injection & Soak Period



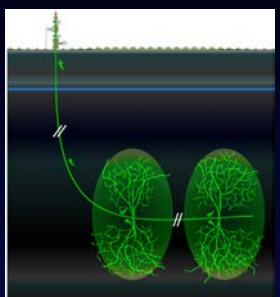
PHYSICS OF GAS INJECTION EOR (CONT.)



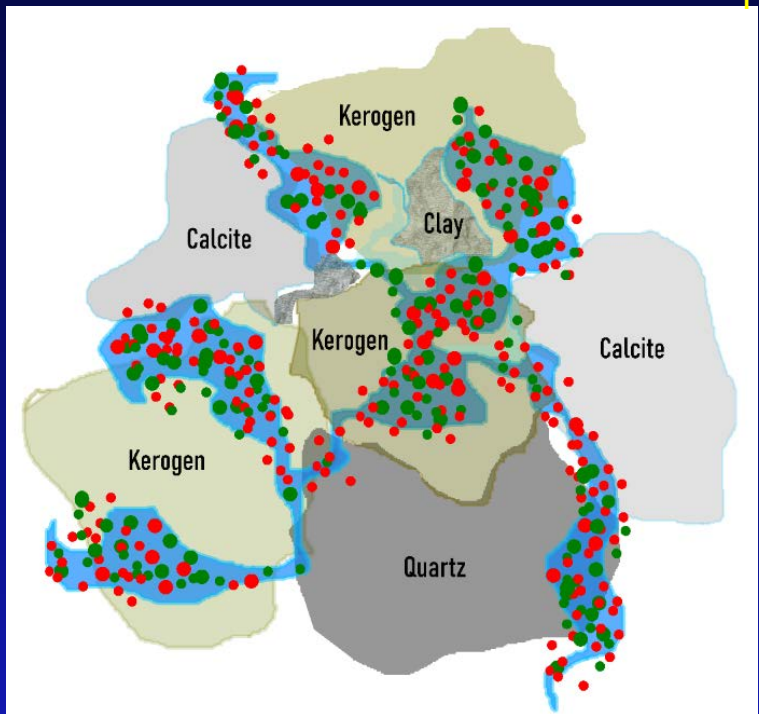
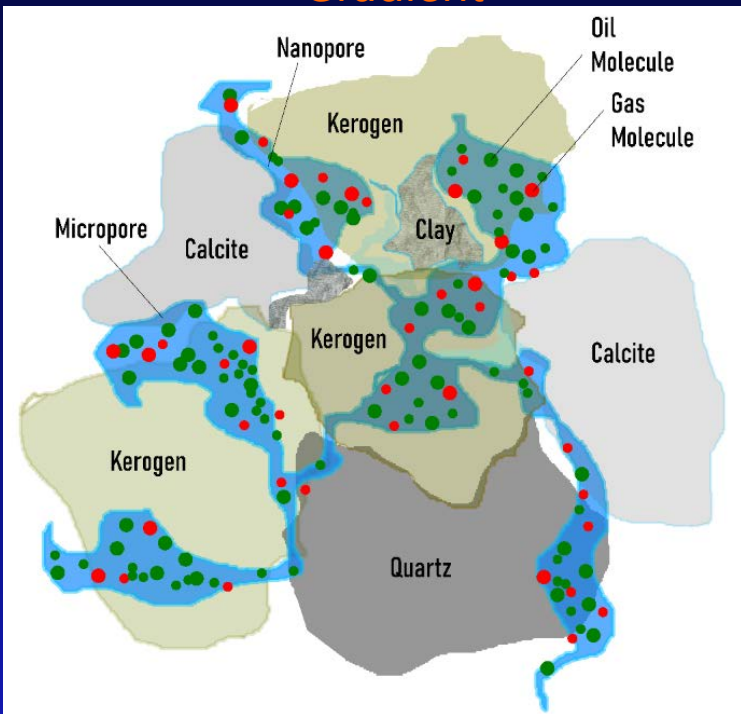
Injection Period
Pressure
Gradient



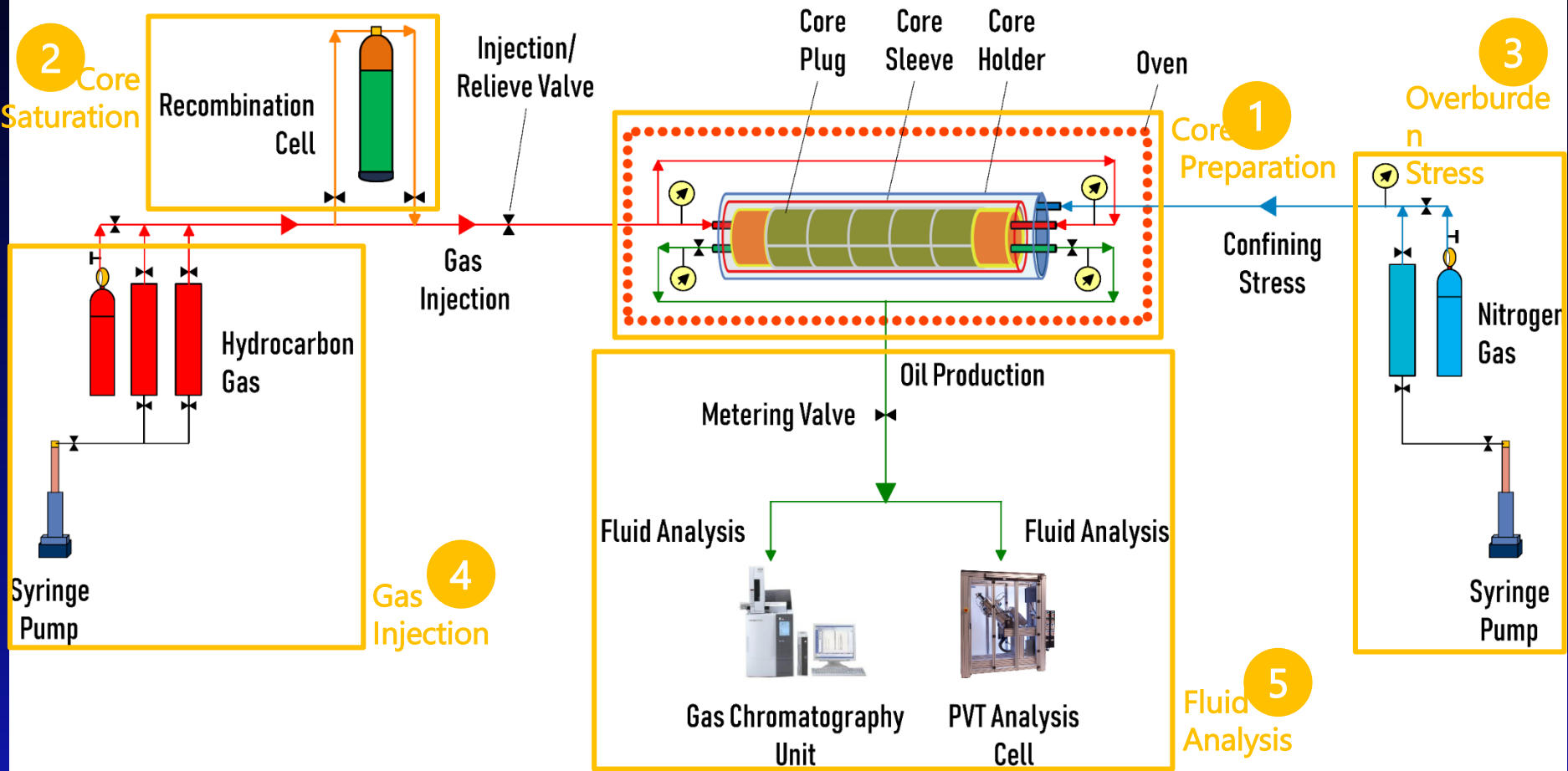
Soak Period
Molecular
Diffusion



Production
Period



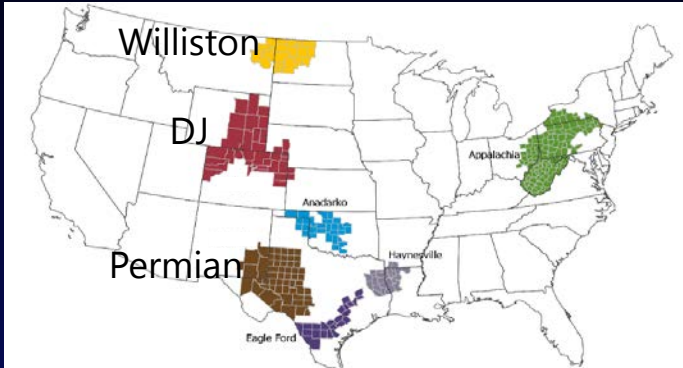
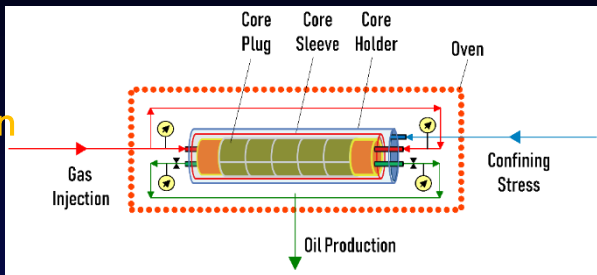
GAS INJECTION EOR LABORATORY SETUP



GAS INJECTION FOR LABORATORY EXPERIMENT

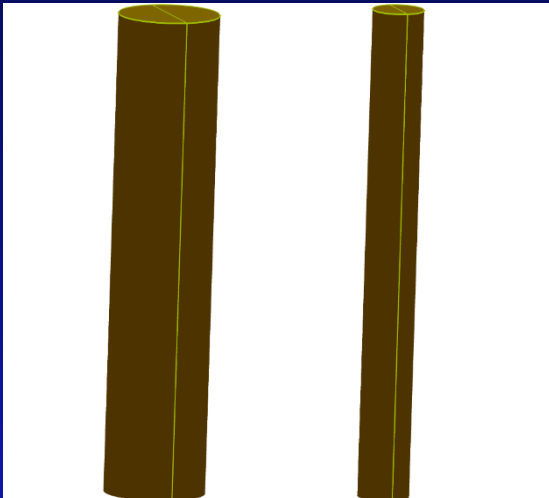
CORE PREPARATION

1
Core Preparation

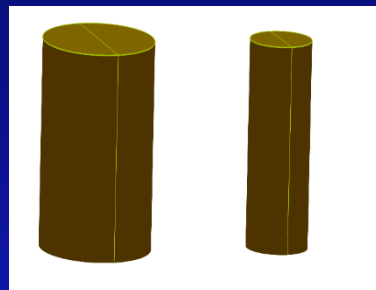


U.S. Energy Information Administration, 2018

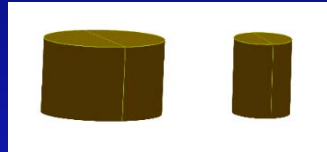
12" Length 12" Length
2.5" Diameter 1.5" Diameter
4 No 4 No



6" Length 6" Length
2.5" Diameter 1.5" Diameter
4 No 4 No



2" Length 2" Length
2.5" Diameter 1.5" Diameter
2 No 2 No



GAS INJECTION EOR LABORATORY EXPERIMENT

CORE PREPARATION (CONT.)

1 Core Preparation

Central, end-to-end hole

Longitudinal Fracture

Transverse Fracture

Fractured & Propped Core

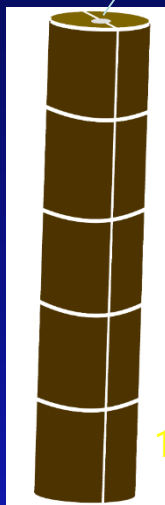
Fractured & Unpropped Core

Core Cleaning

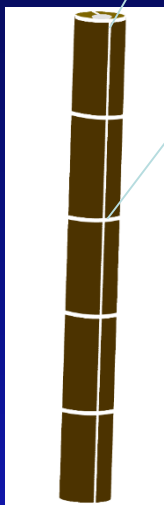
(Coretest Systems, 2018)

Unfractured Core

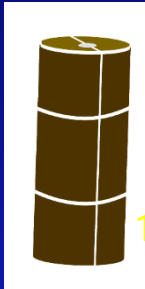
12" L
1.5" Dia
4 No



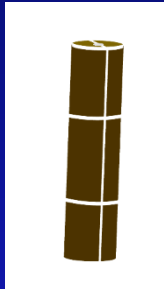
12" L
1.5" Dia
4 No



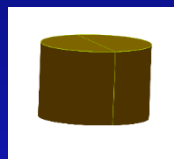
6" L
2.5" Dia
4 No



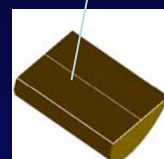
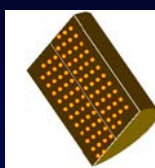
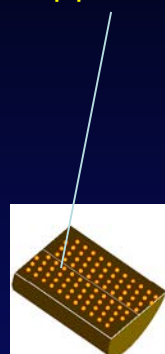
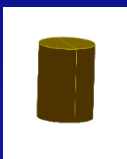
6" L
1.5" Dia
4 No



2" L
2.5" Dia
2 No



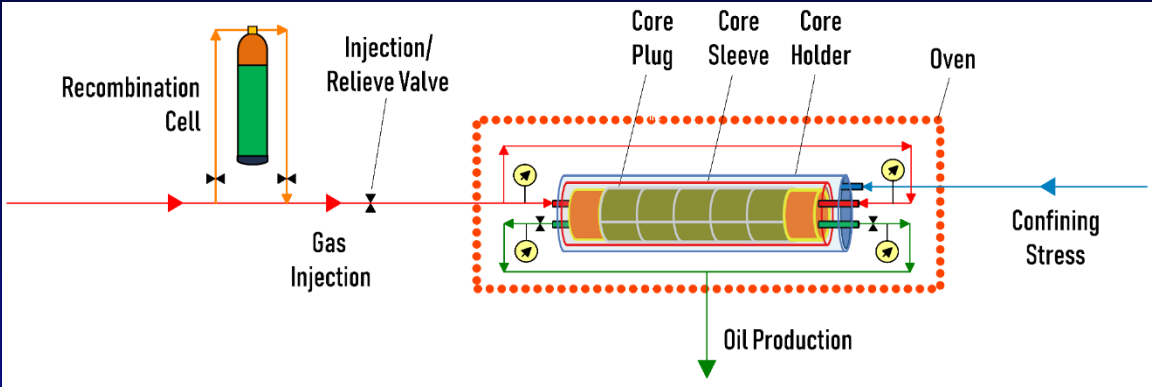
2" L
1.5" Dia
2 No



GAS INJECTION FOR LABORATORY EXPERIMENT

CORE SATURATION

2
Core Saturation

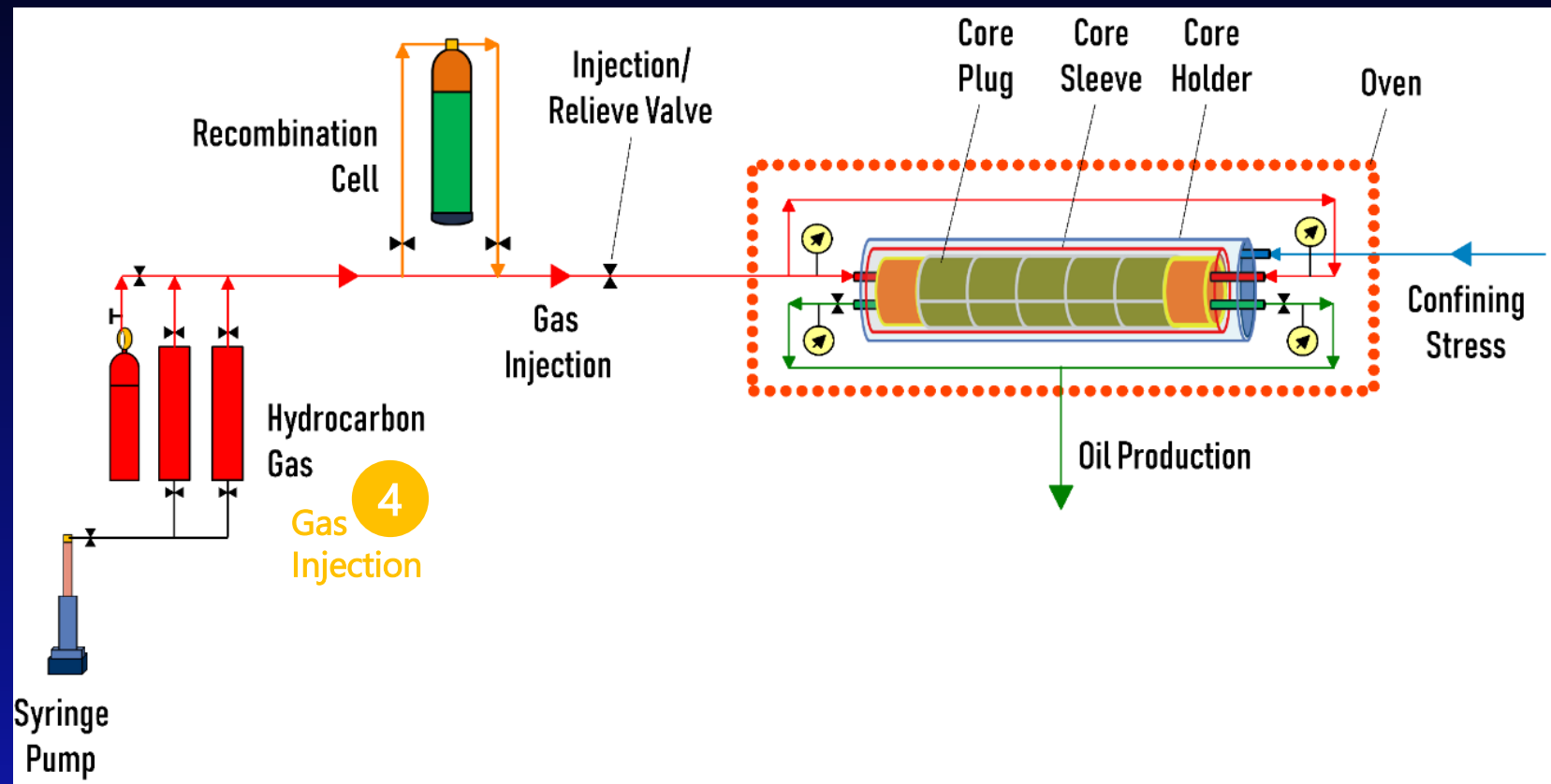


Recombination Cell
(Future Lab Equipment)



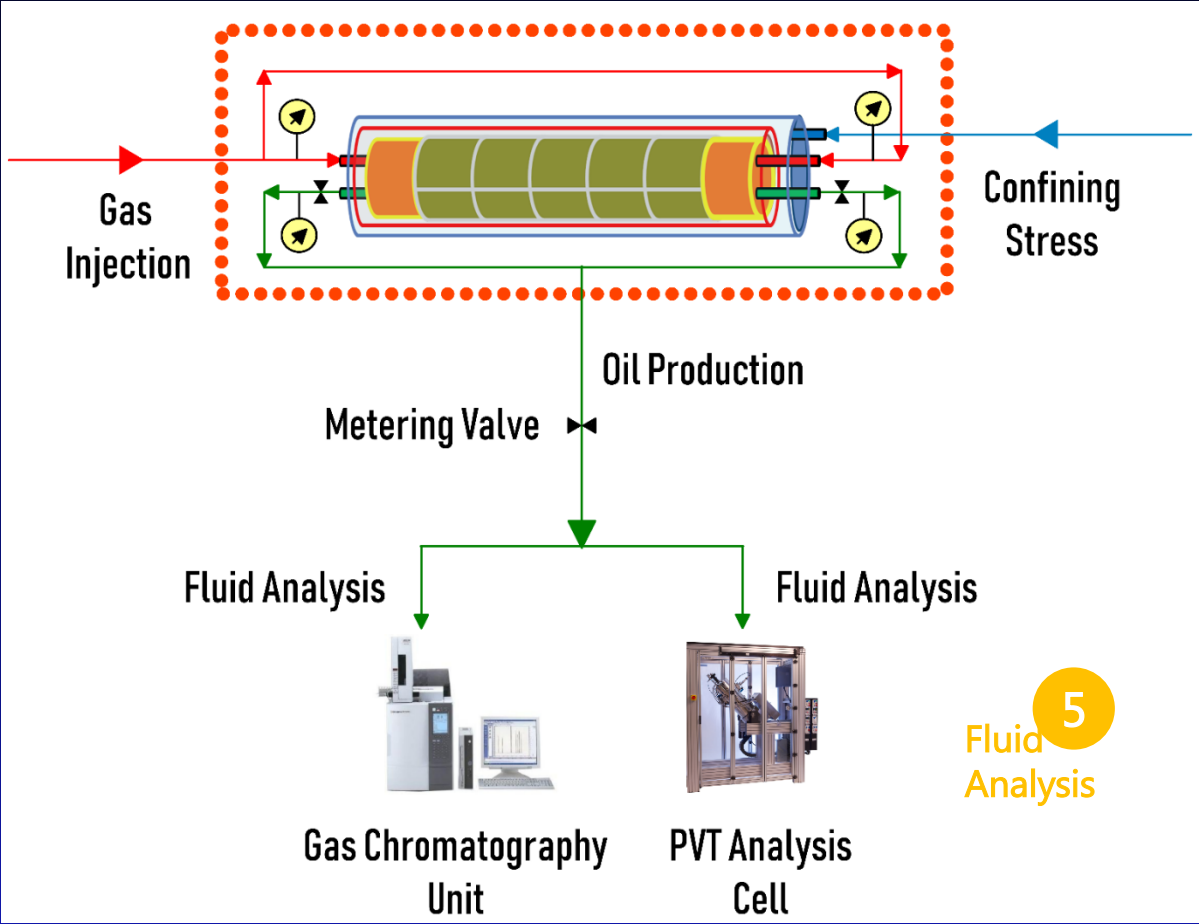
GAS INJECTION EOR LABORATORY EXPERIMENT

SELECTION OF INJECTION GAS



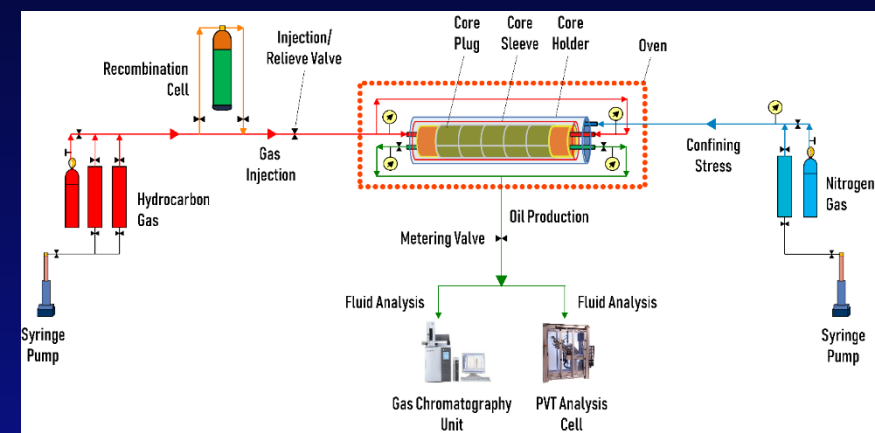
GAS INJECTION EOR LABORATORY EXPERIMENT

FLUID ANALYSIS

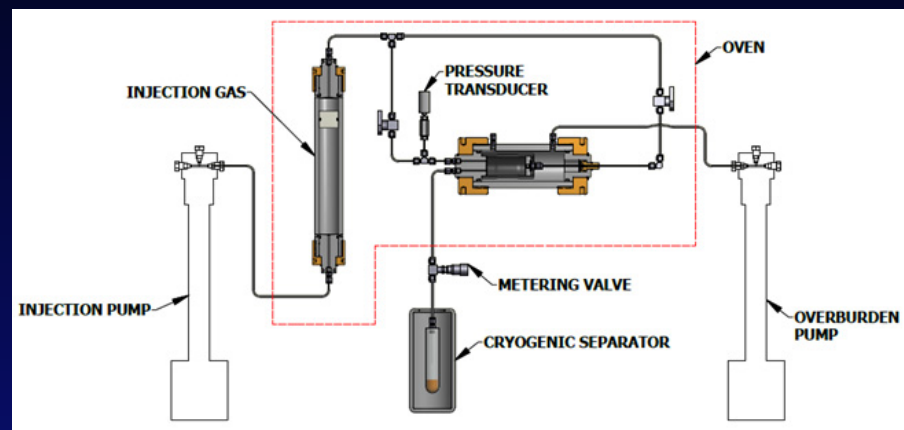


SPECIFICS OF CORE FLOODING APPARATUS

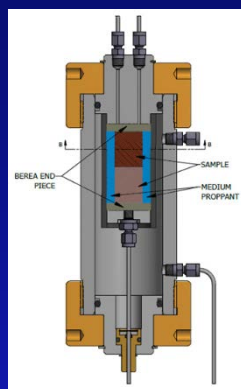
Proposed Gas Inj. EOR Lab Design



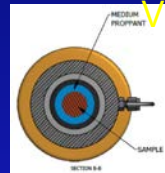
Gas Cycling System (Future Lab Equipment)



Core Holder (Cut View)



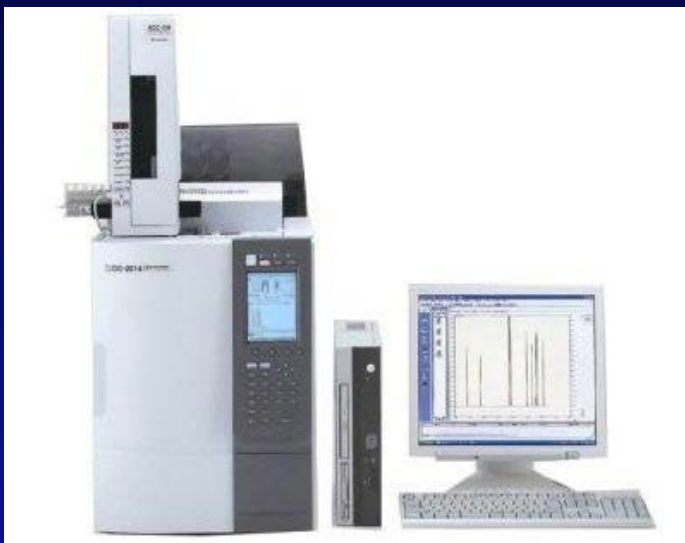
Core Holder (X-Section View)



CORE FLOODING AUXILIARY EQUIPMENT

Existing Lab Equipment

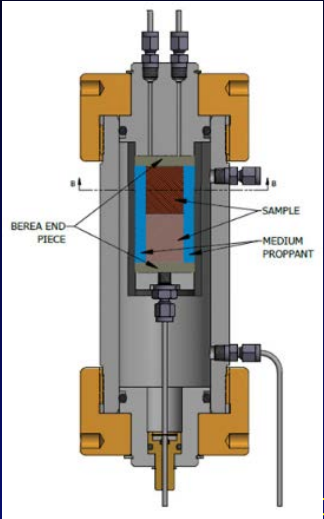
Gas Chromatography Unit
(Fluid Analysis)
\$80,000



PVT Analysis Cell
(Fluid Analysis)
\$480,000

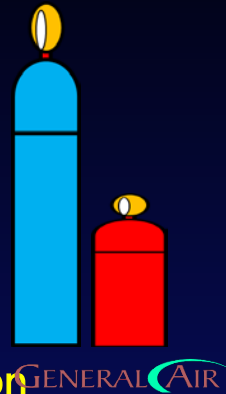


BUDGET FOR LAB DEVELOPMENT

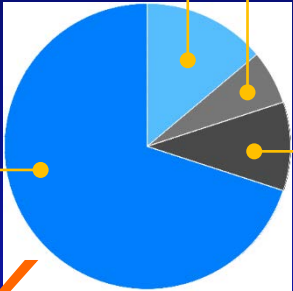


\$120,000
Recombination Cell

\$30,000
Gas & Fluid Preparation

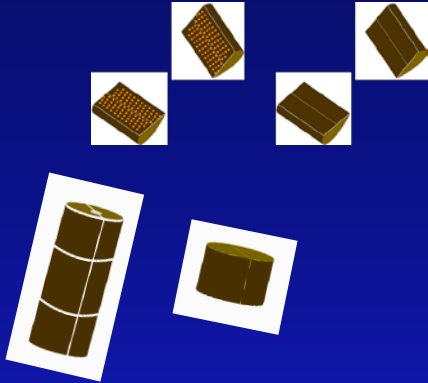


\$270,000
Gas Cycling System



~ \$500K

\$50,000
Core Study



NEEDS AND TIMELINE

- **Funding support for:**
 - Laboratory experiments
 - Field pilot test
- **Cores from shale plays of interest**
- **Timeline:**
 - Laboratory work: 2019, 2020, and 2021
 - Field pilot: ?



U.S. Energy
Information
Administration,
2018



CONCLUDING REMARKS

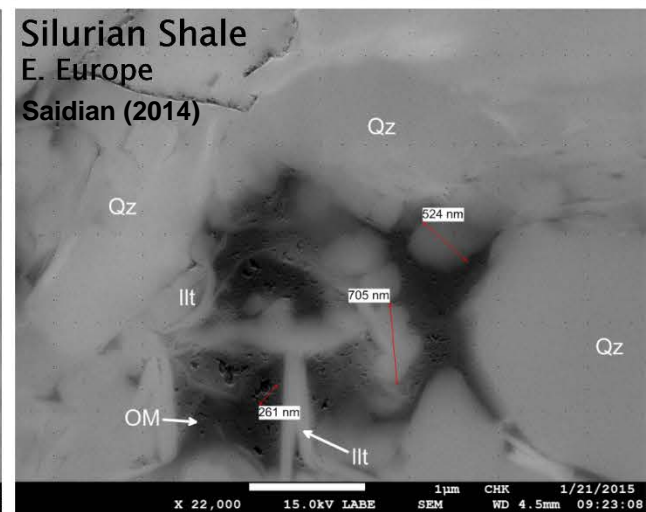
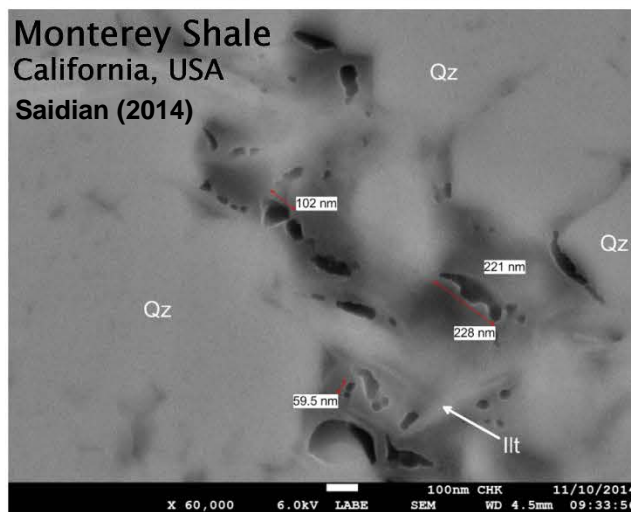
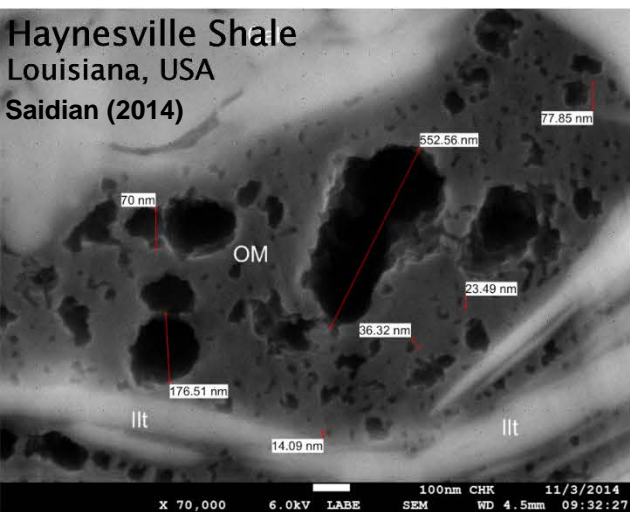
- **We are proposing to build a core flooding apparatus** to conduct gas injection EOR experiments to determine **incremental oil recovery** in unconventional shale cores.
- **We are seeking industry interest** in conducting an EOR field pilot test.
- **We look forward to your positive response and participation.**



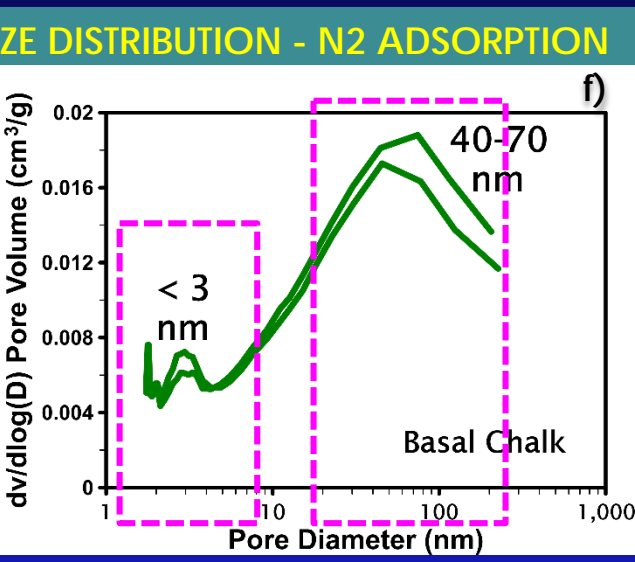
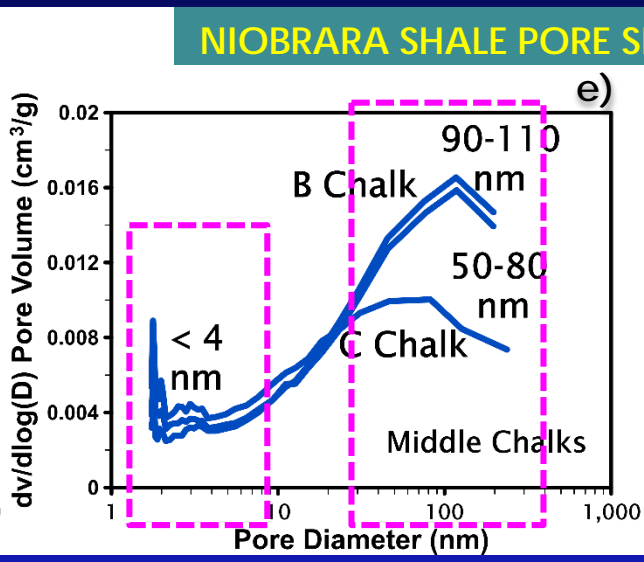
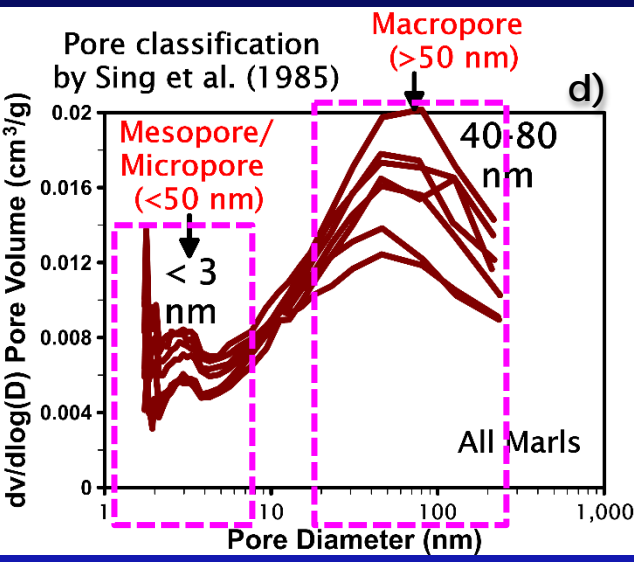
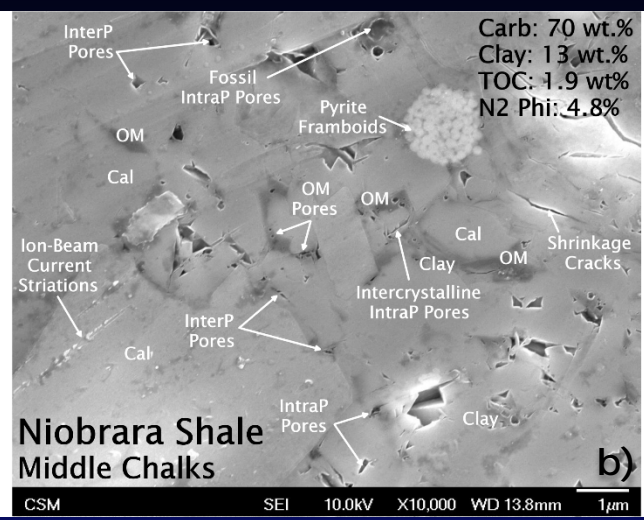
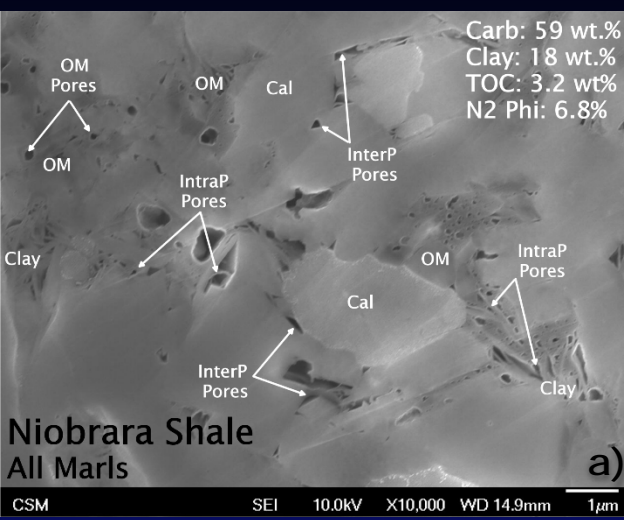
Thank you



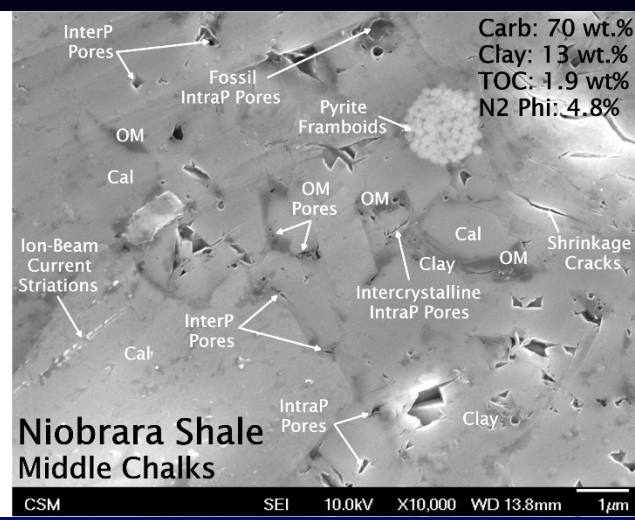
PORE-SIZE DISTRIBUTION EFFECT IN SHALE RESERVOIR PHASE BEHAVIOR



PORE-SIZE DISTRIBUTION EFFECT IN SHALE RESERVOIR PHASE BEHAVIOR (cont.)



PORE-SIZE DISTRIBUTION EFFECT IN SHALE RESERVOIR PHASE BEHAVIOR (cont.)



NIOBARRA SHALE PORE-THROAT SIZE DISTRIBUTION - MICP

