Evaluating Production Performance of Permian Basin Wells to Improve Hydrocarbon Recovery

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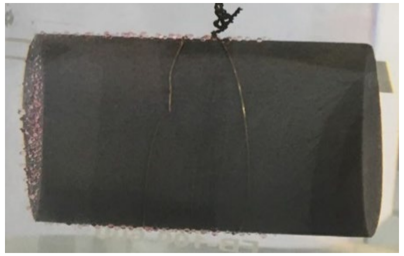
Previous Work

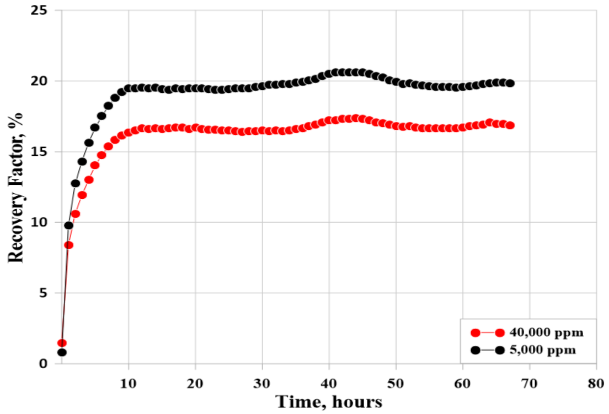
Enhanced Oil Recovery for Liquid-Rich Unconventional Shale Reservoirs Using Low-Salinity and Wettability Altering Dilute Surfactants

Codell Sandstone

5,000 ppm outside, 40,000 ppm inside



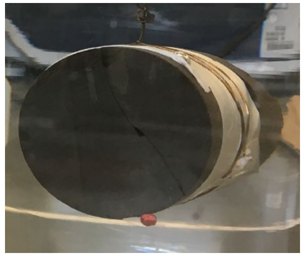
40,000 ppm outside, 40,000 ppm inside



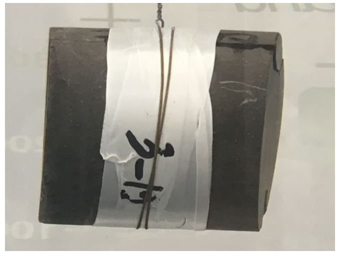
Osmosis increases hydrocarbon recovery 3%

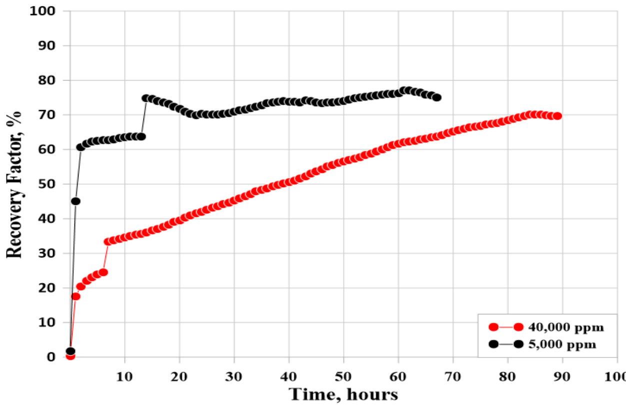
Niobrara B-Chalk

5,000 ppm outside 40,000 ppm inside



40,000 ppm outside 40,000 ppm inside

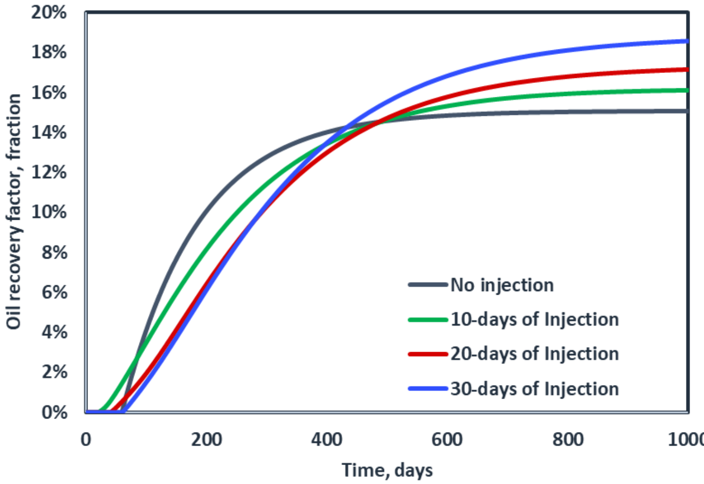




Osmosis increases hydrocarbon recovery 5%

Numerical Model

Low salinity water injection



Osmosis increases hydrocarbon recovery 3%

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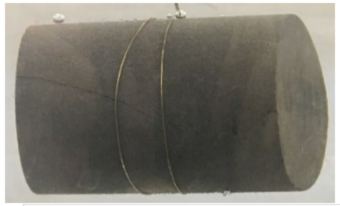
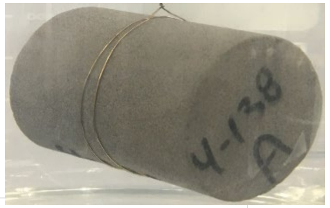
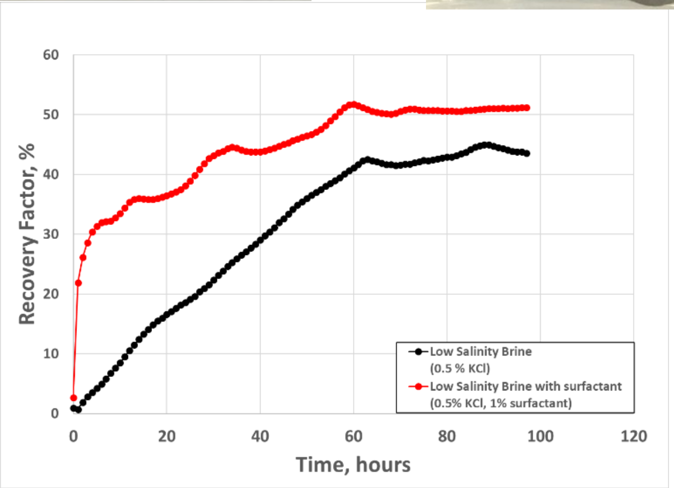


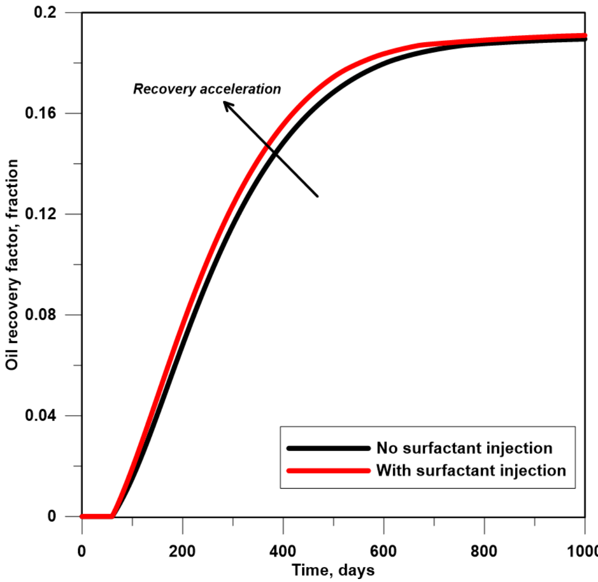
5,000 ppm KCl brine and 10,000 ppm non-ionic surfactant outside, 40,000 ppm inside

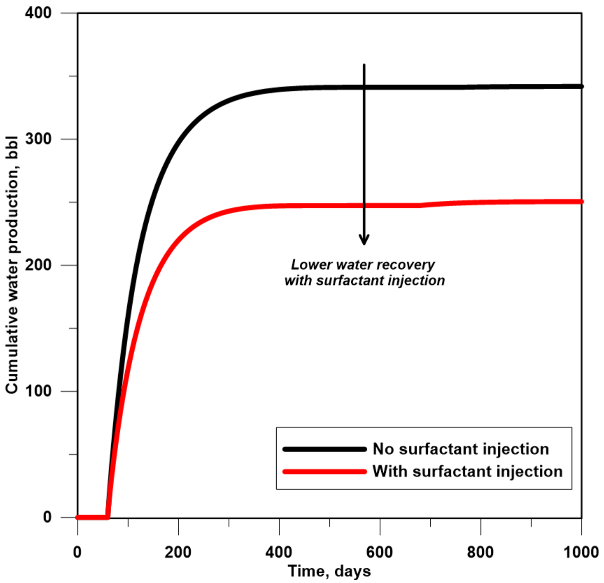




Low salinity brine with non-ionic surfactant increases hydrocarbon recovery with additional 6%

Numerical Model





- Oil recovery accelerated
- Decrease in IFT between oil-water results in higher imbibition, thus lowering the water production.

Problem Statement

- **Permian Basin** is the most prolific oil and gas producing geologic basins in the United Sates, spanning West Texas and Southeastern New Mexico. It has produced more than 33.4 Bbbl of oil and 118 Tcf of natural gas during a 100-year period (EIA 2018).

- The ever-increasing water production and usage in the Permian Basin requires attention—it is a major issue.

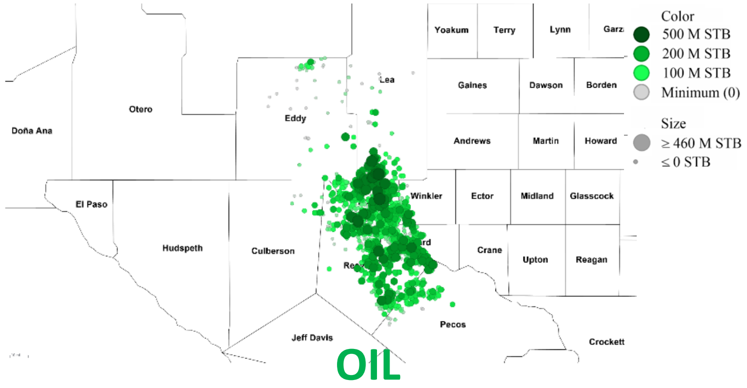
- Classical waterflooding in unconventional reservoirs is not plausible because of the small pore size and low permeability of the mudstone matrix.

- The practical alternative is **cyclic or continuous gas injection** which is one objective of my research to increase oil production.

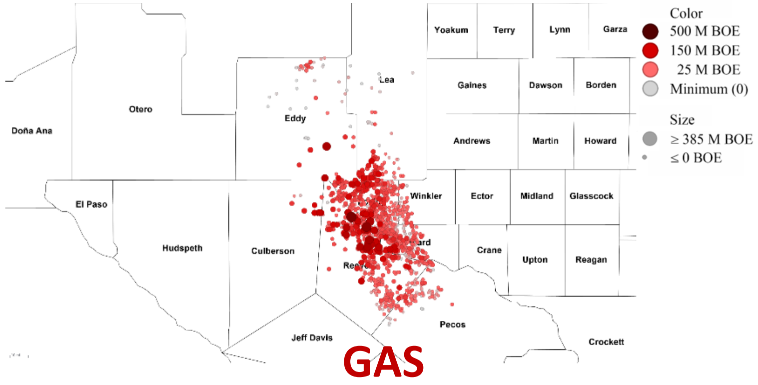
Recap - Production Trends

Performance of Oil Wells

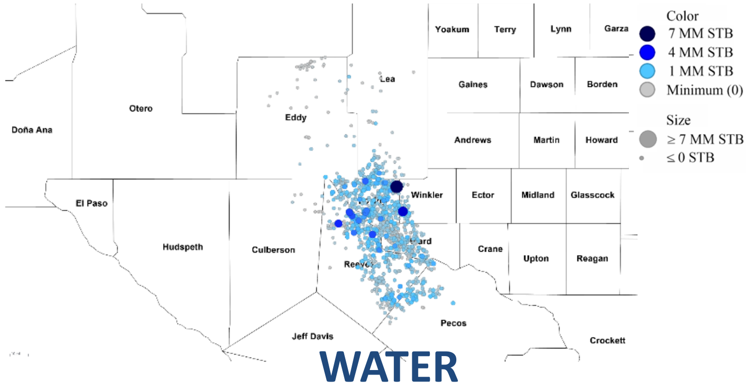
12 Months



12 Months

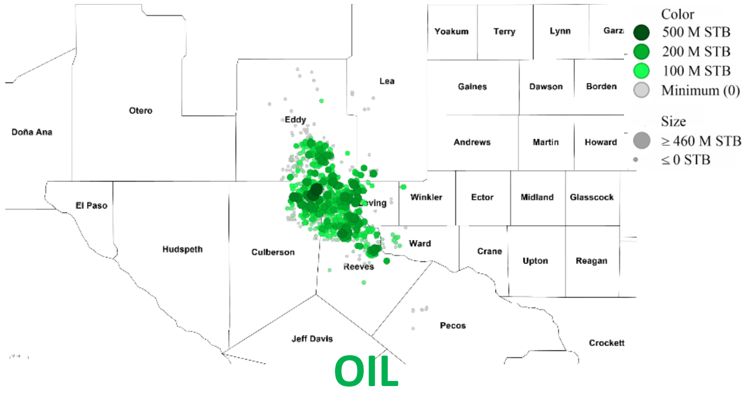


12 Months

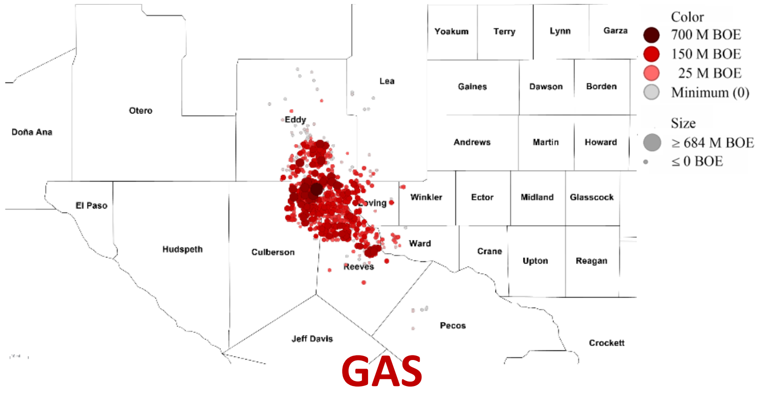


Performance of Gas Wells

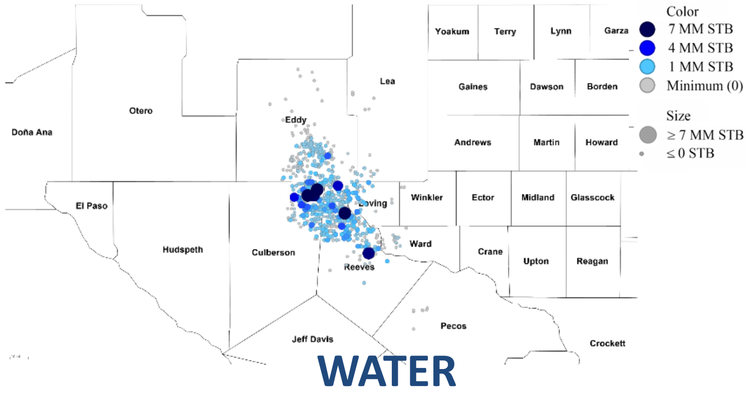
12 Months



12 Months

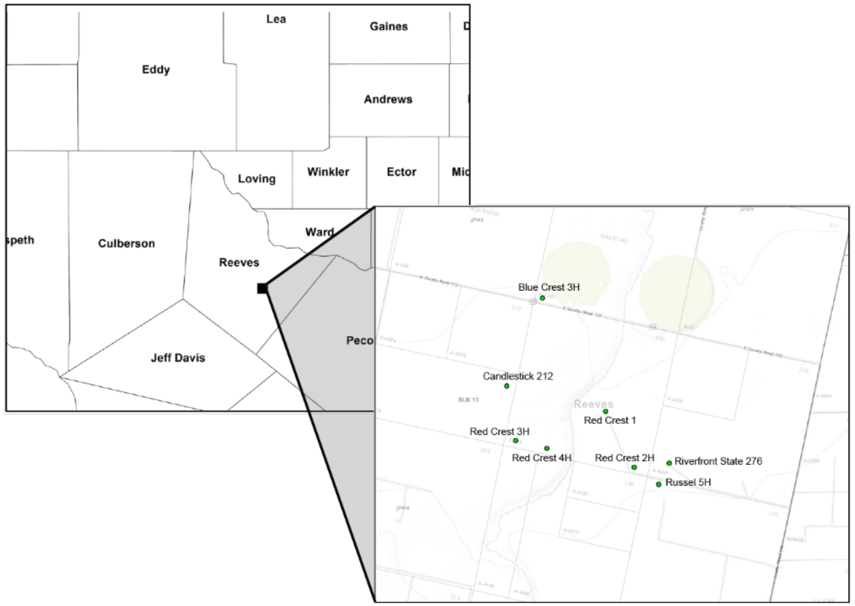


12 Months

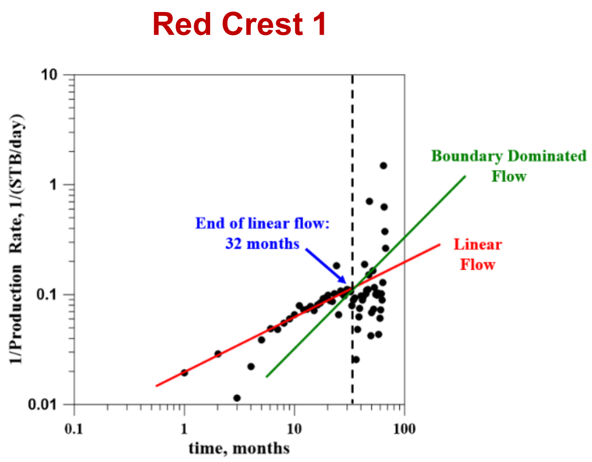


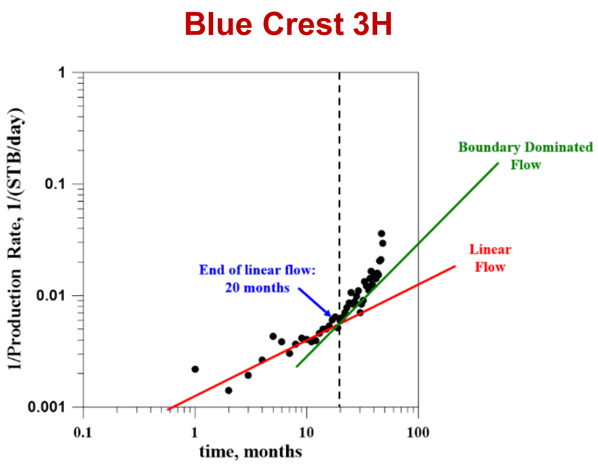
(Source: Enverus 2019)

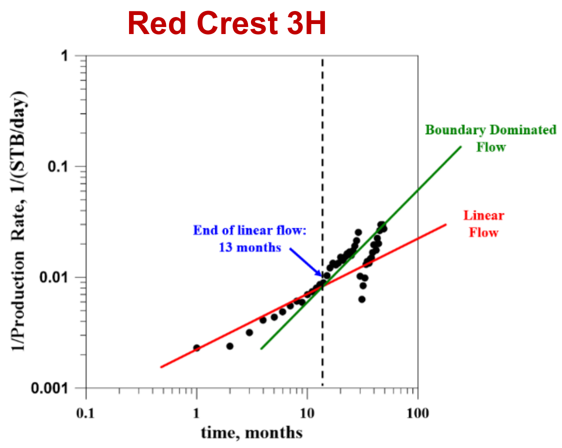
Recap - RTA Analysis



Well Name	Drill Type	End of Linear Flow Regime (months)	Cumulative Production End of Linear Flow (STB)
Red Crest 1	V	32	17,631
Riverfront State 276	V	31	50,019
Russel 5H	H	19	88,142
Candlestick 212	H	24	93,750
Red Crest 4H	H	7	84,941
Red Crest 3H	H	13	87,695
Red Crest 2H	H	12	148,148
Blue Crest 3H	H	19	166,682

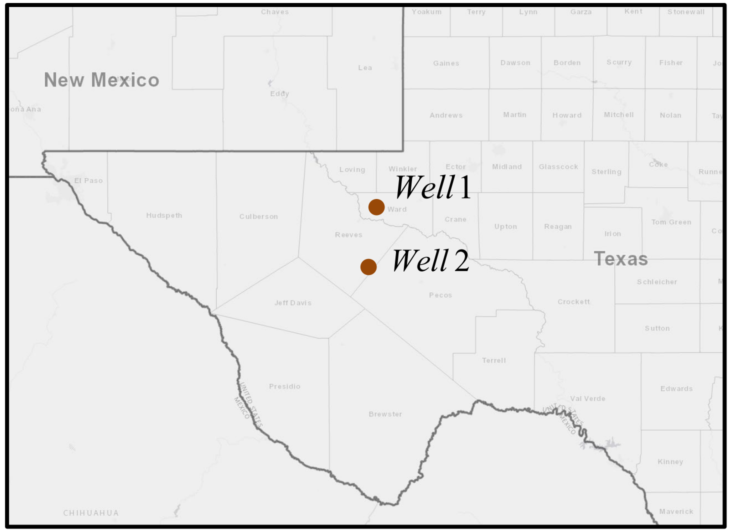




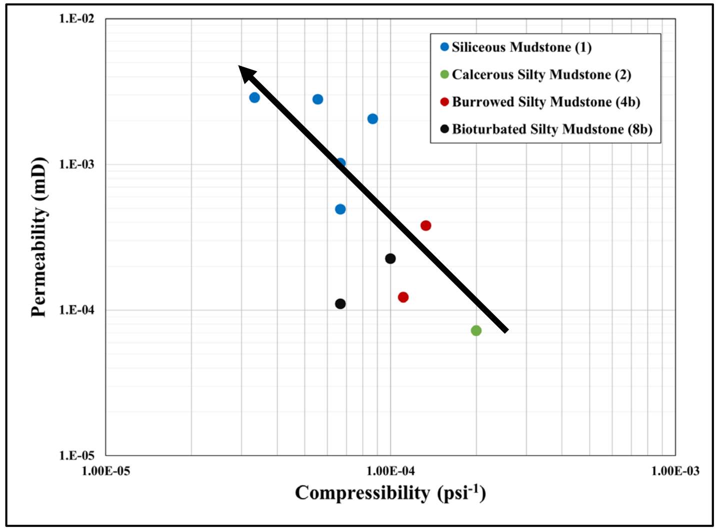


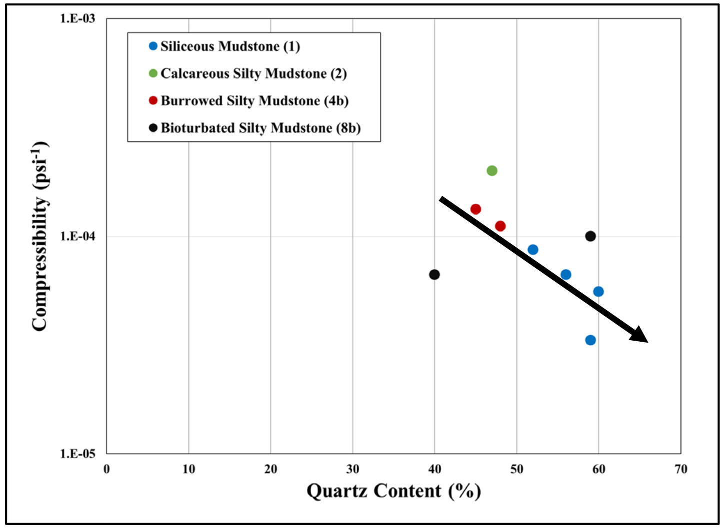
(Source: Enverus 2019)

Recap - Compressibility vs Permeability/Quartz Content



(Source: Enverus 2019)





- Decreasing compressibility with increasing Quartz content

- Effect on Brittleness

$$\frac{1}{c} = K = \frac{E}{3(1-\upsilon)}$$

$$B = \frac{100\left(\frac{E-1}{8-1} + \frac{\upsilon - 0.4}{0.15-0.4}\right)}{2}$$

(Rickman et al. 2008)

$$B = 100\left(\frac{Quartz}{Quartz + Calcite + Clay}\right)$$

(Jarvie et al. 2007)

$where;$

$c = compressibility\,(psi^{-1})$

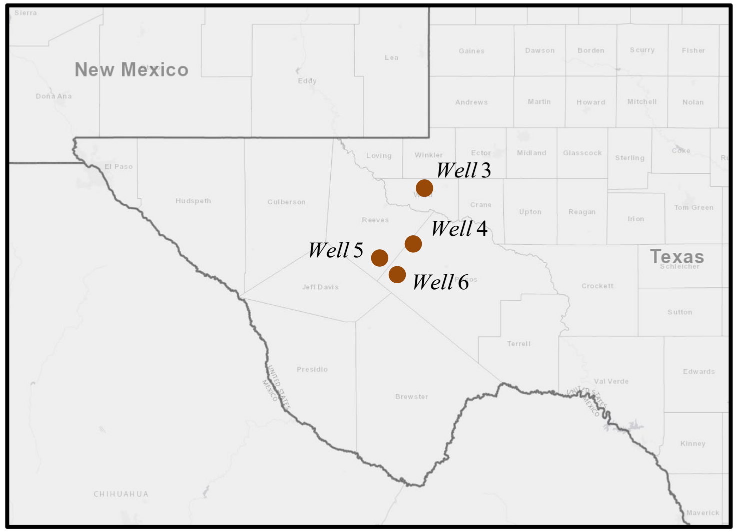
$K = Bulk\ Modulus\,(psi)$

$E = Young's\ Modulus\,(psi)$

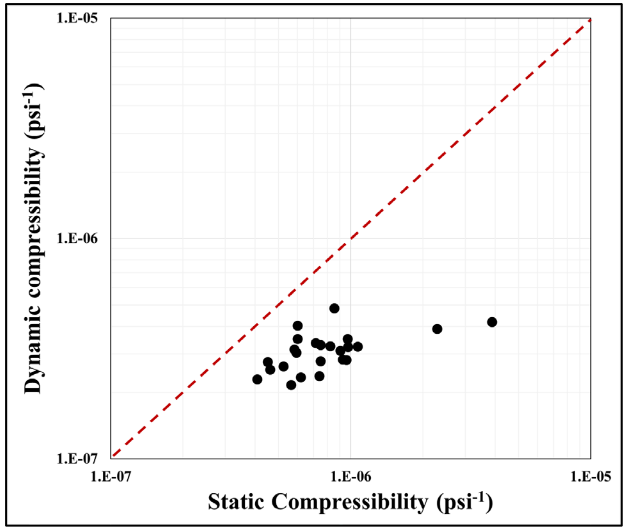
$\upsilon = Poisson's\ Ratio$

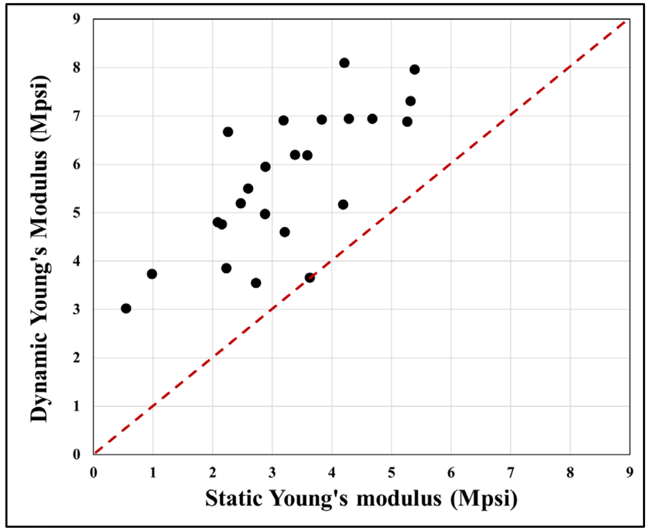
$B = Brittleness\ Index$

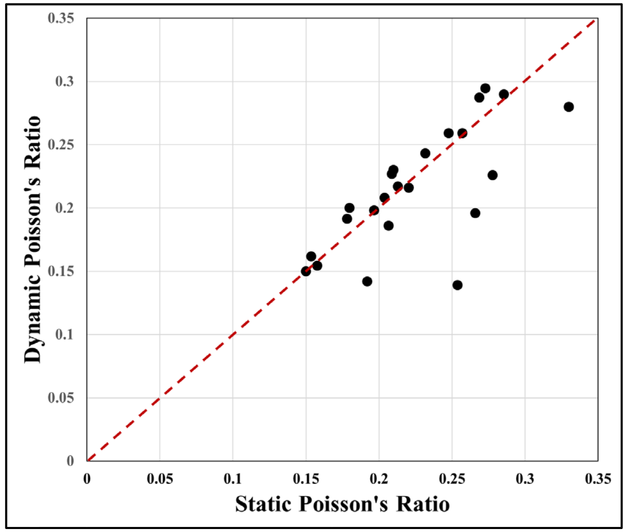
Recap - Elastic Rock Properties

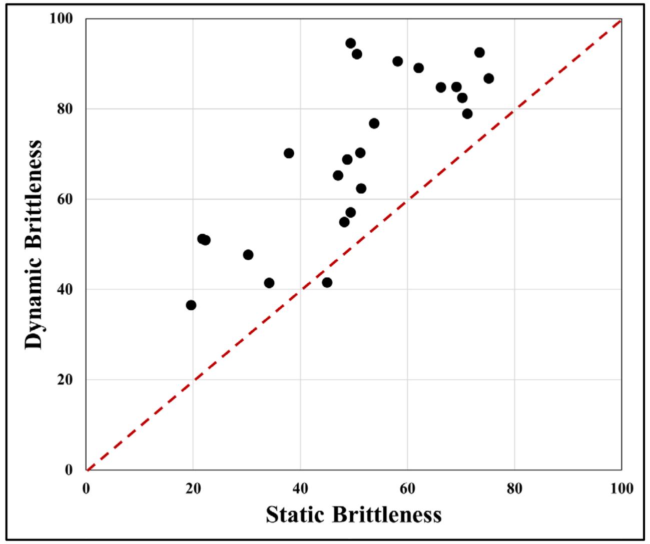


(Source: Enverus 2019)



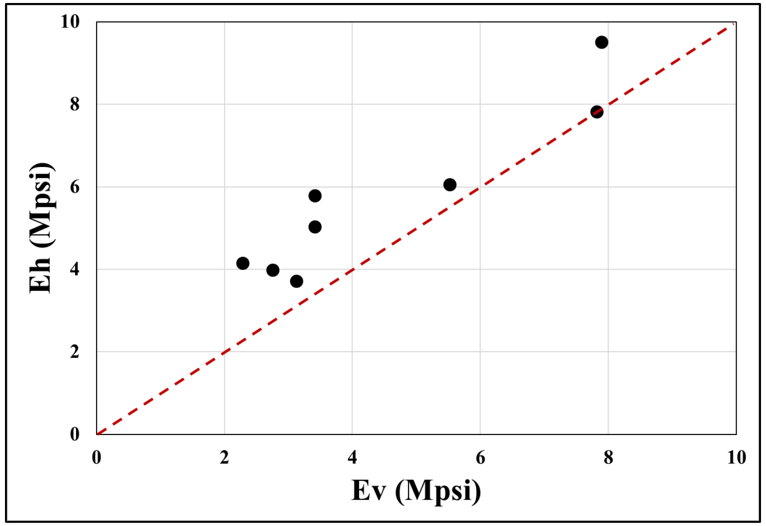




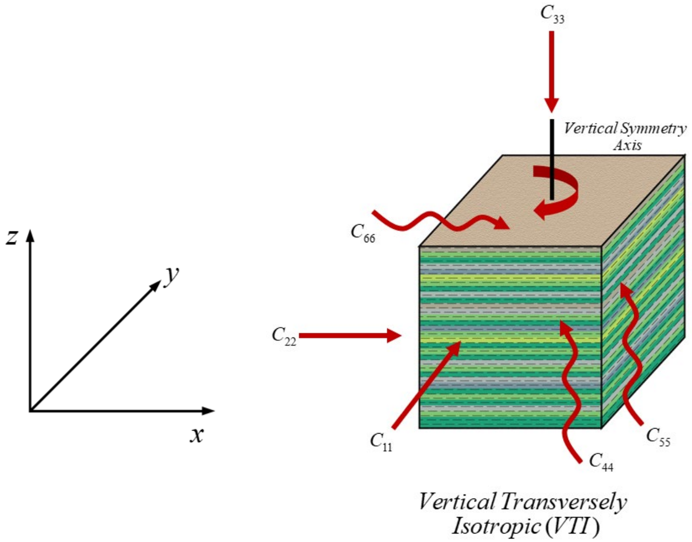


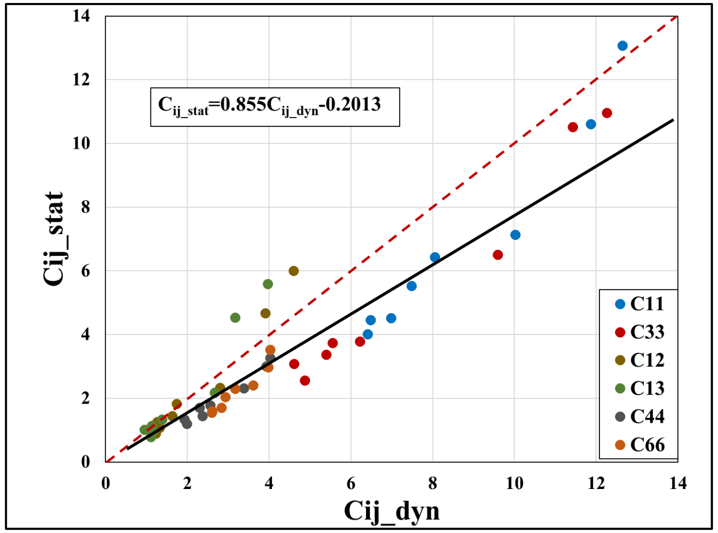
- Comparison of static vs dynamic properties from four wells
- Expected unconventional reservoir behavior
- Higher dynamic Young’s modulus
- Higher brittleness index

Recap - Geomechanical Model

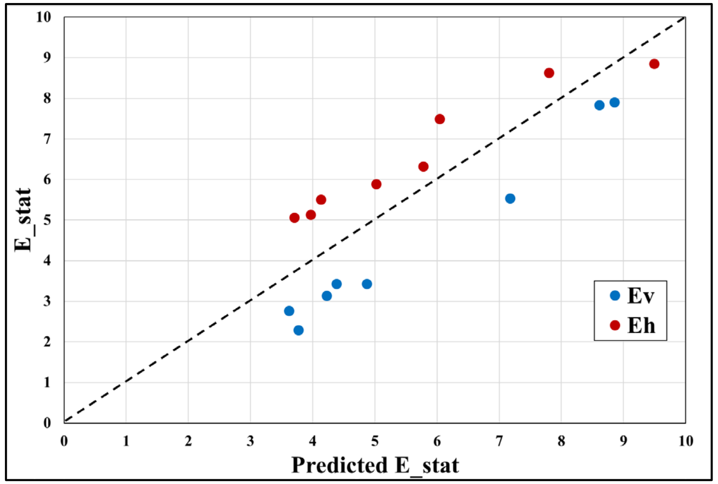


$E_h \geq E_v$ VTI system behavior





Static-dynamic Relationship

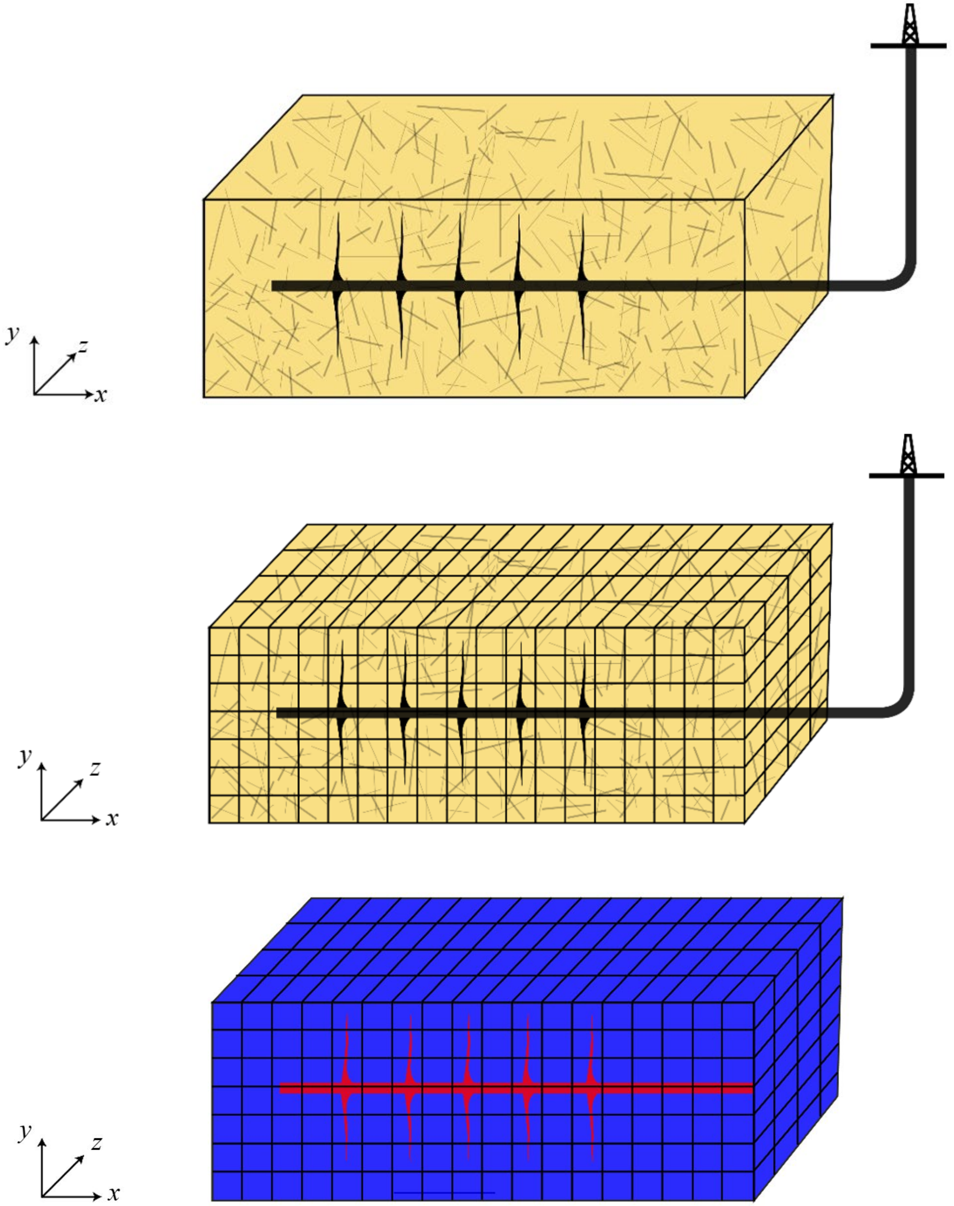


Validation for the back-calculated static moduli = 86%

Statement of Work

- **Step 1:**
- Understanding the production trends and behavior of the wells in Delaware Basin
- Preliminary experimental work
- **Step 2:**
- Building a numerical model
- Preparation for the experiments
- **Step 3:**
- Conducting experiments
- History matching the production data using numerical model
- Automated interpretation

Current Work – Dual Porosity Model



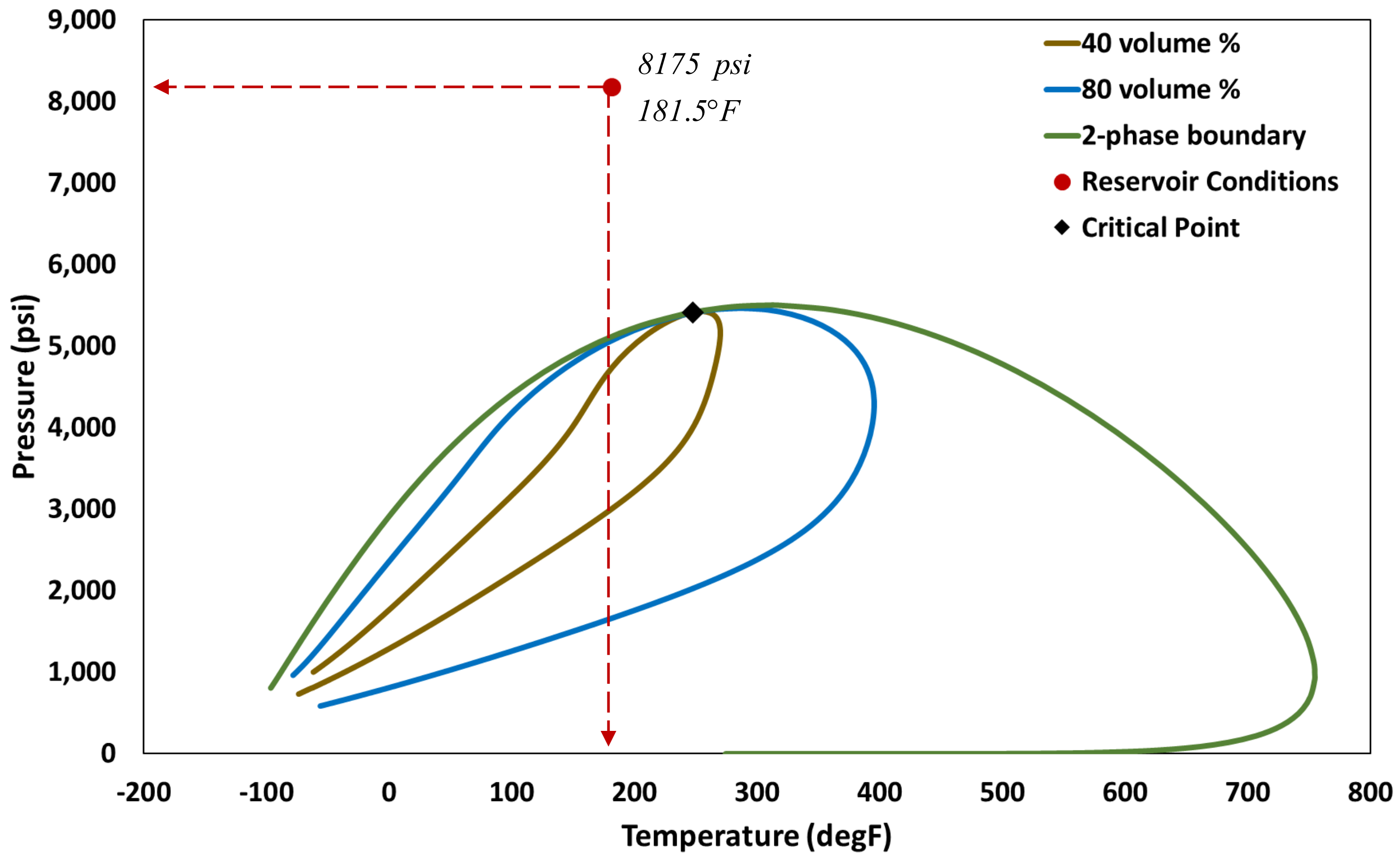
Required Data for Numerical Model

- Rock Properties (ϕ, k, etc.)
- Fluid Properties (Composition, Viscosity, etc.)
- Pressure profile (Daily pressure data)
- Rate profile (Daily rate data)
- Completions data (Stimulation report, well design)

Current Work - Summary of Reservoir Properties

• Thickness:	400 ft
• Initial res pressure:	8175 psia
• Reservoir temp:	181.5 °F
• Porosity:	0.08
• Matrix permeability:	0.004 mD
• Matrix pore compressibility:	1×10^{-5} $psia^{-1}$

Current Work - Fluid Model



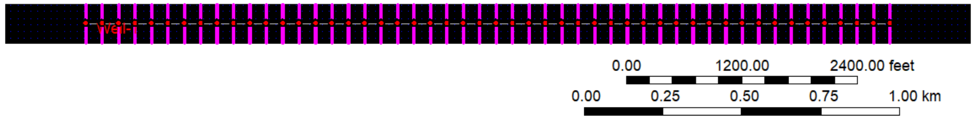
Component	Mole Percent
N_2 to CO_2	0.9
CH_4	67.59
C_2H_6	9.24
C_3H_8	5.51
IC_4 - NC_4	2.79
IC_5 - FC_6	2.31
FC_7 - FC_{10}	5.62
FC_{11} - C_{15}	2.98
FC_{16} - C_{22}	1.69
FC_{23} - C_{30+}	1.35

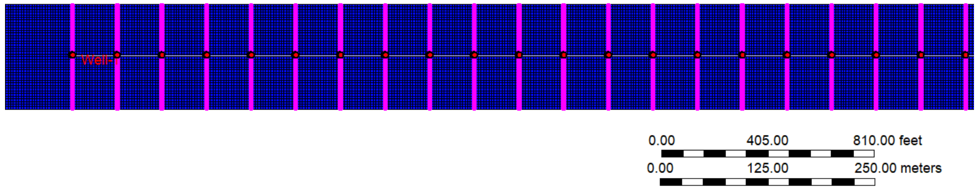
Current Work - Model Grid Structure

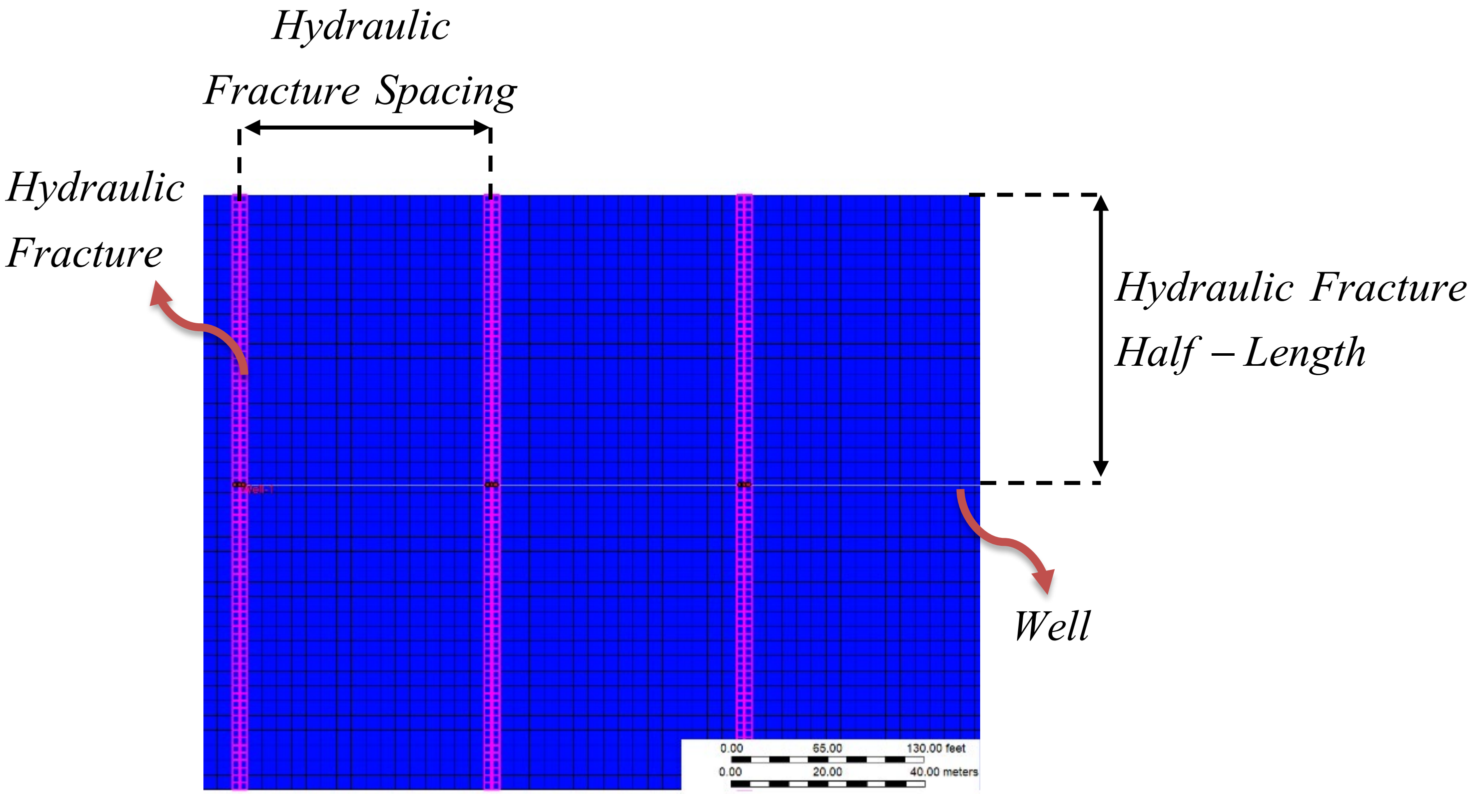
- IMAX : 1000
- JMAX : 40
- KMAX : 40

Δx : 10 ft
Δy : 10 ft
Δz : 10 ft

50 HF stages







Current Work - Model Rock Properties

Matrix

Property	Value	Unit
Porosity	0.08	-
Permeability	0.004	mD
Compressibility	1×10^{-5}	$psia^{-1}$

Natural Fractures

Property	Value	Unit
Porosity	0.01	-
Effective permeability	0.01	mD
Compressibility	1×10^{-5}	$psia^{-1}$

Property	Value	Unit
L_x	1	ft
L_y	1	ft
L_z	1	ft
σ	12	ft^{-2}

Current Work - Initial Model Inputs

Matrix

Property	Value	Unit
Initial reservoir pressure	8175	psi
Initial water saturation	0.4	-
Global composition, CH_4	67.59	Mole %
Global composition, C_2H_6	9.24	Mole %
Global composition, C_3H_8	5.51	Mole %
Global composition, IC_4 - NC_4	2.79	Mole %
Global composition, IC_5 - FC_6	2.31	Mole %
Global composition, FC_7 - FC_{10}	5.62	Mole %
Global composition, FC_{11} - C_{15}	2.98	Mole %
Global composition, FC_{16} - C_{22}	1.69	Mole %
Global composition, FC_{23} - C_{30+}	1.35	Mole %

Natural Fractures

Property	Value	Unit
Initial reservoir pressure	8175	psi
Initial water saturation	0.05	-
Global composition, CH_4	67.59	Mole %
Global composition, C_2H_6	9.24	Mole %
Global composition, C_3H_8	5.51	Mole %
Global composition, IC_4 - NC_4	2.79	Mole %
Global composition, IC_5 - FC_6	2.31	Mole %
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Global composition, FC_{11} - C_{15}	2.98	Mole %
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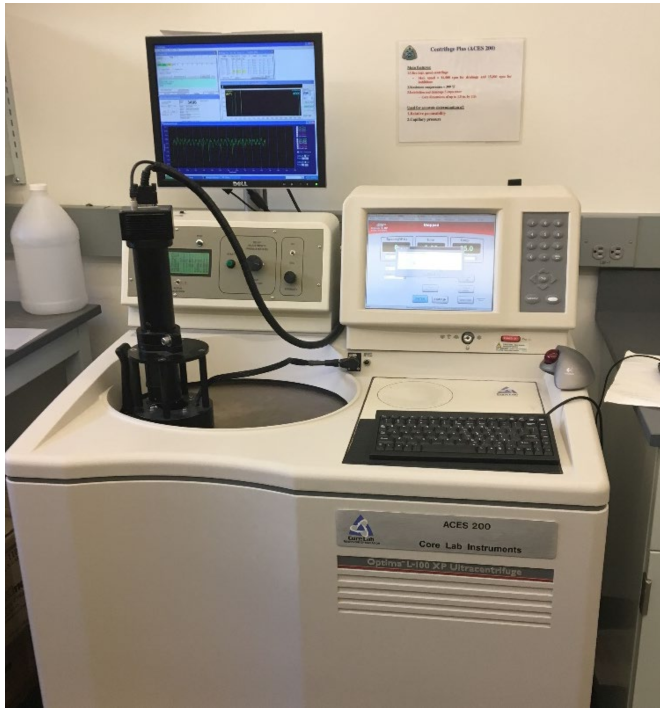
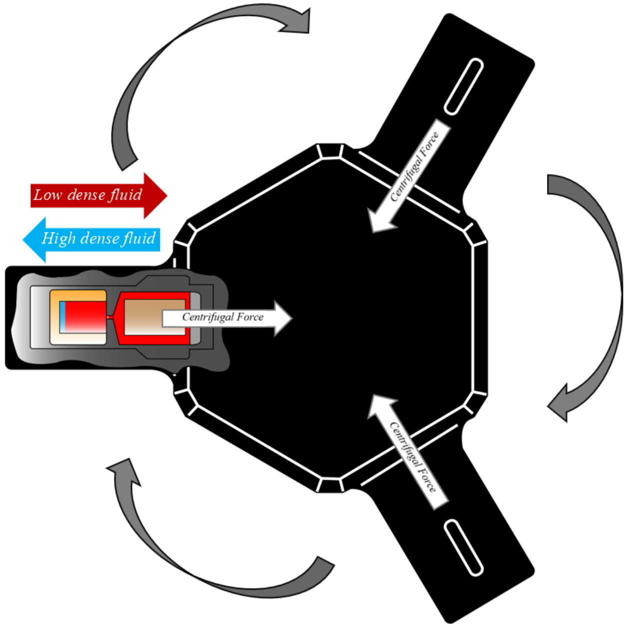
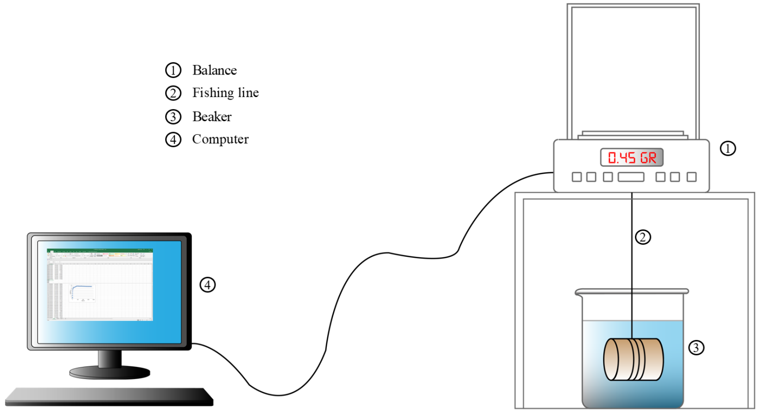
Future Work - Laboratory Experiment and Procedures

Capillary Pressure – Relative Permeability





(Uzun 2018)



Ultra-High-Speed Centrifuge (ACES-200)

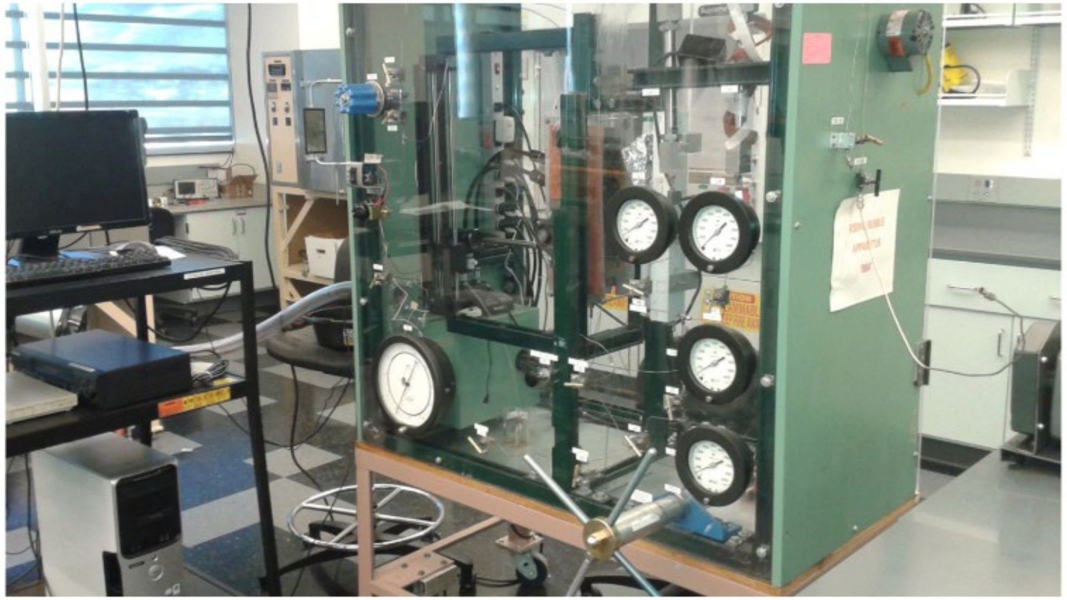
Saturation Measurement Apparatus

- Capillary Pressure
- Relative Permeability

- Drainage (15,500 RPM maximum speed)
- Forced Imbibition (16,500 maximum speed)

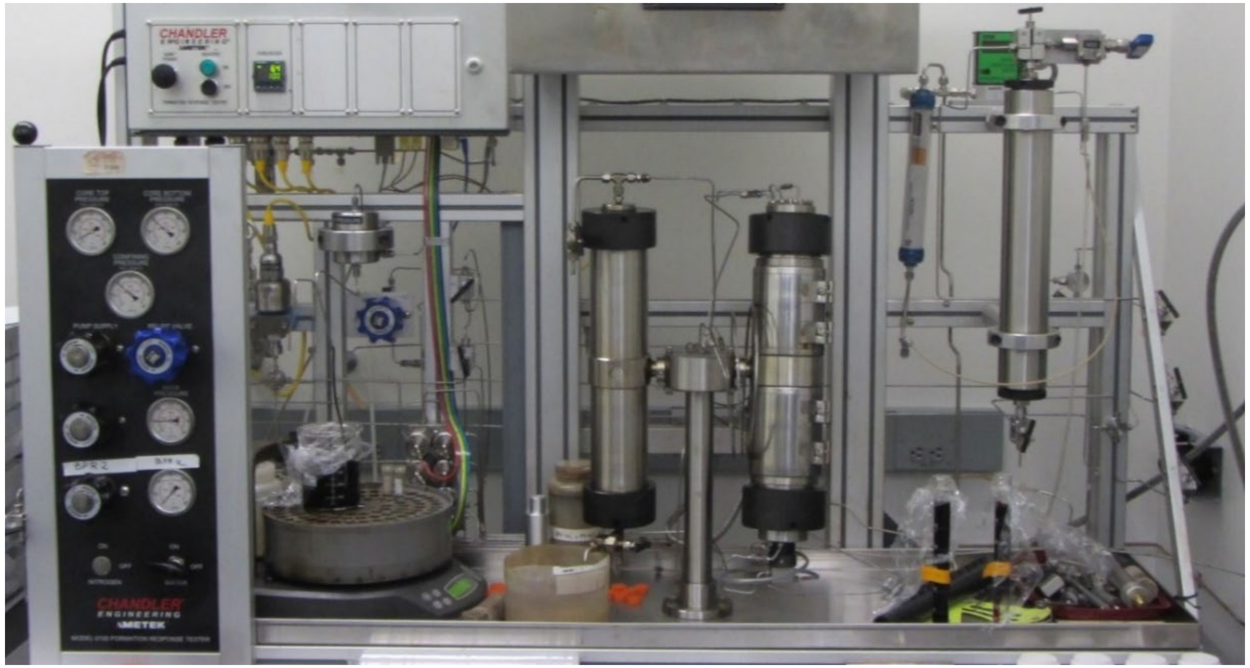
Future Work - Laboratory Experiment and Procedures

Core Flooding – Gas Injection



Rising Bubble Apparatus (RBA)

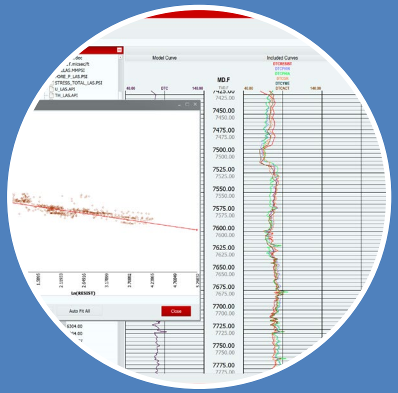
- Determination of Minimum Miscibility Pressure (MMP)



Formation Response Tester (FRT-6100)

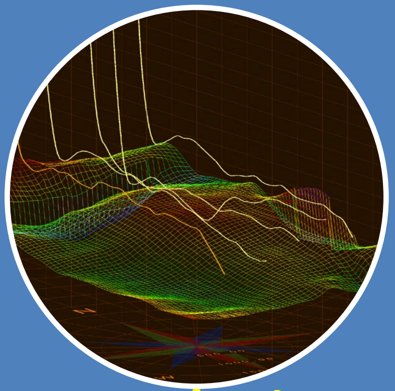
- Core flooding experiments in reservoir conditions (P,T)

Future Work - GOHFER Project



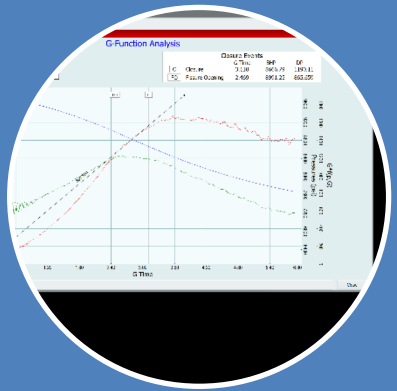
Petrophysics

LAS files → Reservoir and mechanical rock properties



Geologic Modeling

Earth models or surface structure maps → Spatially variable reservoir and mechanical properties

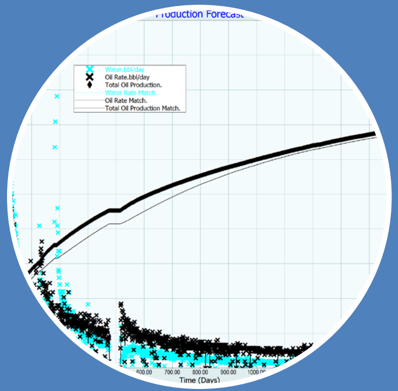


Diagnostics

DFIT analysis

Fracture Simulation

Multi-disciplinary, integrated geomechanical fracture simulator



Production Analysis

RTA, DCA

Statistical Analysis of Fracture Treatment and Production Data to **Optimize** Designs

Future Work - GOHFER Project

Phase 1 – Integration of domain expertise and machine learning

Training

Geology & Petrophysics
- Manual interpretation of the logs
- Structural features and sediment architecture
- Geologic model

Automated Interpretation

Machine Learning
- Enhance with existing models (data boost)

Verification

ACKNOWLEDGEMENT

- Dr. Hossein Kazemi (Co-Advisor)
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- Dr. Bob Barree and GOHFER Development Team
- Kathy Emme
- Jim Emme

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