NETL RIC Onshore Unconventional Resources

Alexandra Hakala, Technical Portfolio Leader

NATIONAL ENERGY TECHNOLOGY LABORATORY

U.S. DEPARTMENT OF ENERGY

NETL Science & Technology Strategic Plans & Programs:
Jared Ciferno, Grant Bromhal

HQ Office of Oil and Natural Gas:
Elena Melchert and Olayinka Ogunsola

Primary Research Goals

Enhancing Recovery through Fundamental Knowledge of the Reservoir and Well System

NATIONAL ENERGY TECHNOLOGY LABORATORY

- **Improve Fundamental Understanding of Shale to Enable Decision-Making for Enhanced Recovery**
  - **Geomechanical and Geophysical Processes** Affecting Fracture Behavior and Hydrocarbon Production
  - **Geochemical and Biological Processes** Affecting Fracture Behavior and Hydrocarbon Production

This Presentation

- Ensure Wellbore Integrity during Drilling, Completions, and Production
  - Effects of Chemical and Biological processes on Flow
  - Effects of Mechanical Processes on Flow and Containment

Barbara Kutchko
Thursday 2:40 PM, Rooms 301,302

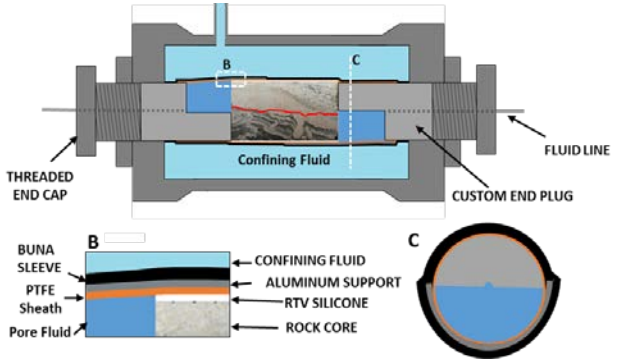
- Systems Analysis for Maximizing Hydrocarbon Value and Produced Water Beneficial Use

Understanding the Reservoir

Identification of reservoir-based processes that impact hydrocarbon production

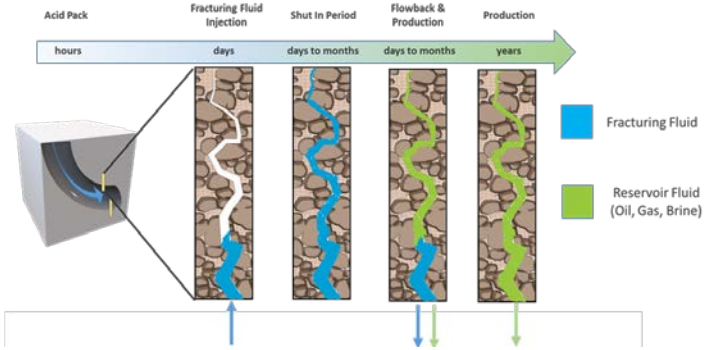
NATIONAL ENERGY TECHNOLOGY LABORATORY

Geomechanics



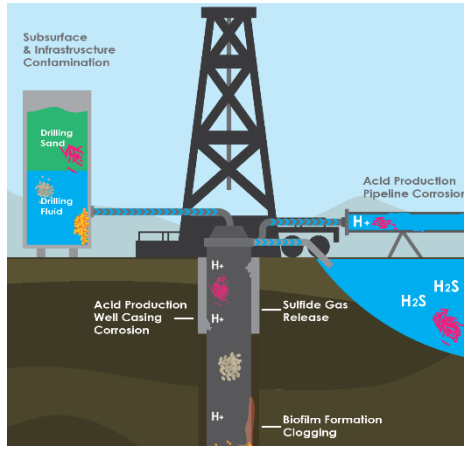
Coupled Effects of Mechanics + Chemistry

Geochemistry

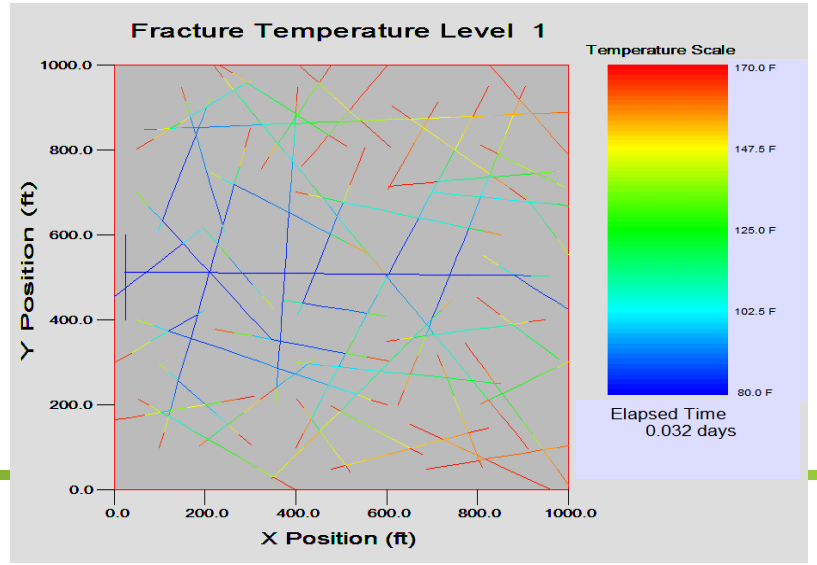


Coupled Effects of Chemistry + Biology

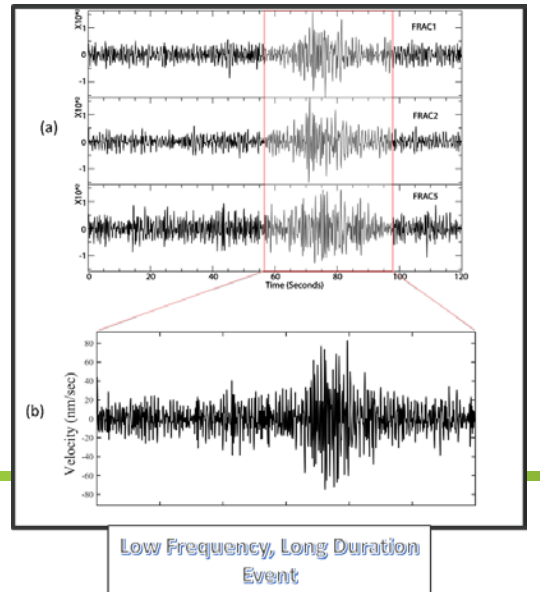
Geobiology



Fracture Modeling



Geophysics

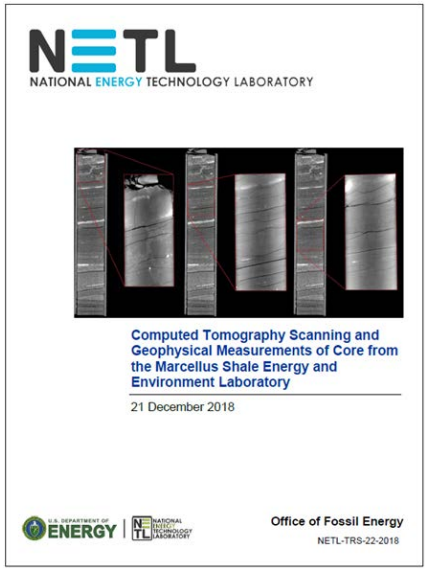


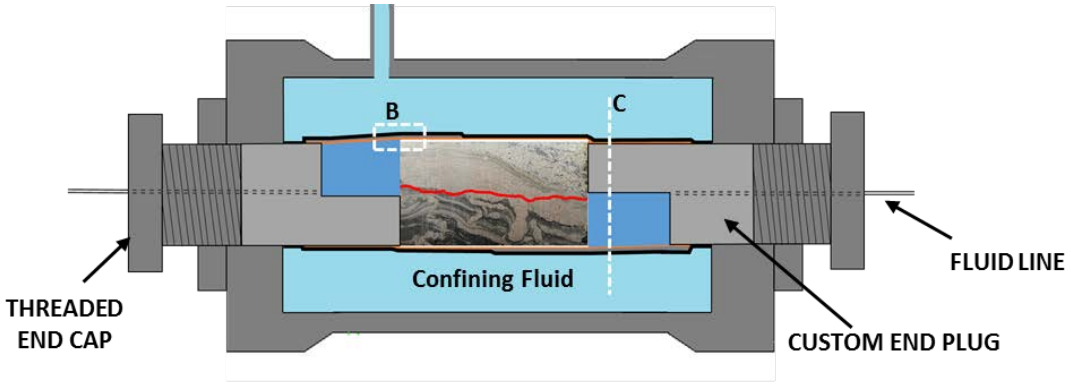
Role of Shale Geomechanical Changes in Affecting Gas and Fluid Flow – Dustin Crandall

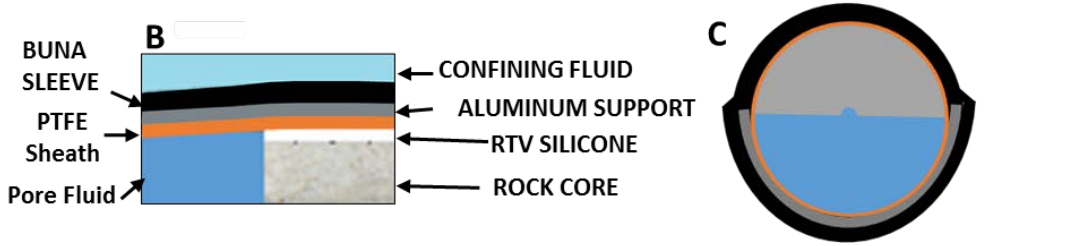
Geomechanical & Geophysical Processes Affecting Fracture Behavior & HC Production

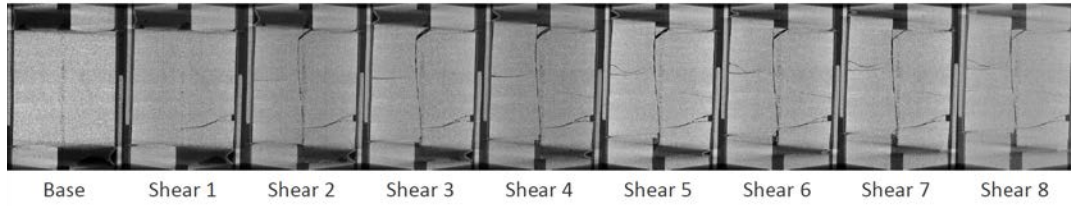
- Knowledge of **fracture shearing behavior and proppant embedment** in shales with different organic and mineral content
- Evaluation of natural gas-EOR for HFTS 1 Site 2
- Collection, documentation, and dissemination of **basic properties of unconventional reservoir cores that can be shared** with and used by multiple stakeholders

Poster Session - Dustin Crandall





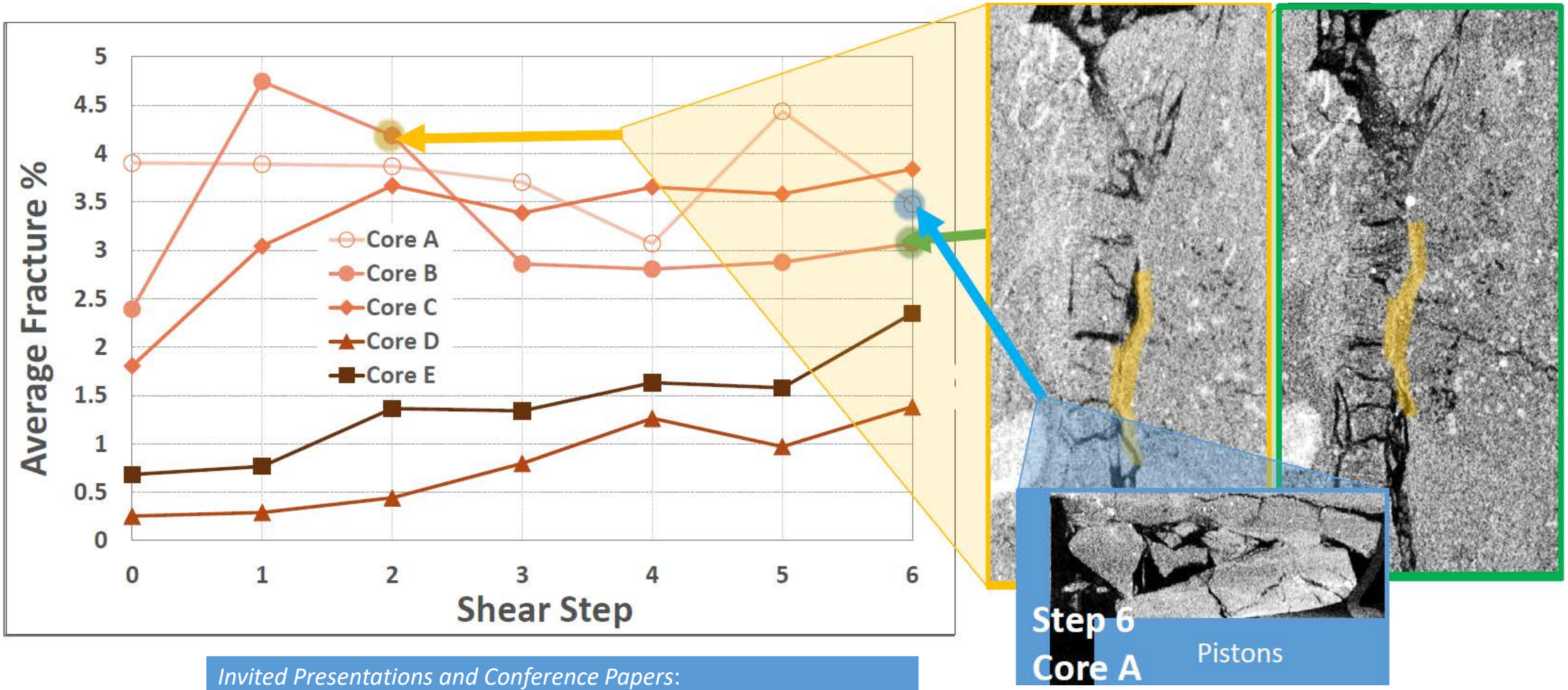




Project Team (NETL): Dustin Crandall, Johnathan Moore, Magdalena Gill, Terry McKisic, Jeong Choi, Thomas Paronish, Paige Mackey, Guanyi Lu, Scott Workman, Bryan Tennant, Aaron Boylen

Role of Shale Geomechanical Changes in Affecting Gas and Fluid Flow – Dustin Crandall

Geomechanical & Geophysical Processes Affecting Fracture Behavior & HC Production



Invited Presentations and Conference Papers:
Crandall (invited), URTeC Workshop Pittsburgh, PA, April 16, 2019
Gill et al., American Rock Mechanics Association, June 23-26, 2019
Crandall et al., URTeC, Denver, CO, July 24-26, 2019

Reservoir Simulation for Representing Coupled P,T Effects on Fractures – Mark McKoy, W. Neal Sams

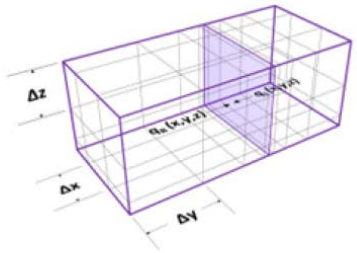
Geomechanical & Geophysical Processes Affecting Fracture Behavior & HC Production

NATIONAL ENERGY TECHNOLOGY LABORATORY

Matrix-Fracture Modeling for P&T

- Updates to NFflow code for dynamic pressure and temperature changes during hydraulic fracturing & primary production

Matrix to Fracture Flows as Discretized

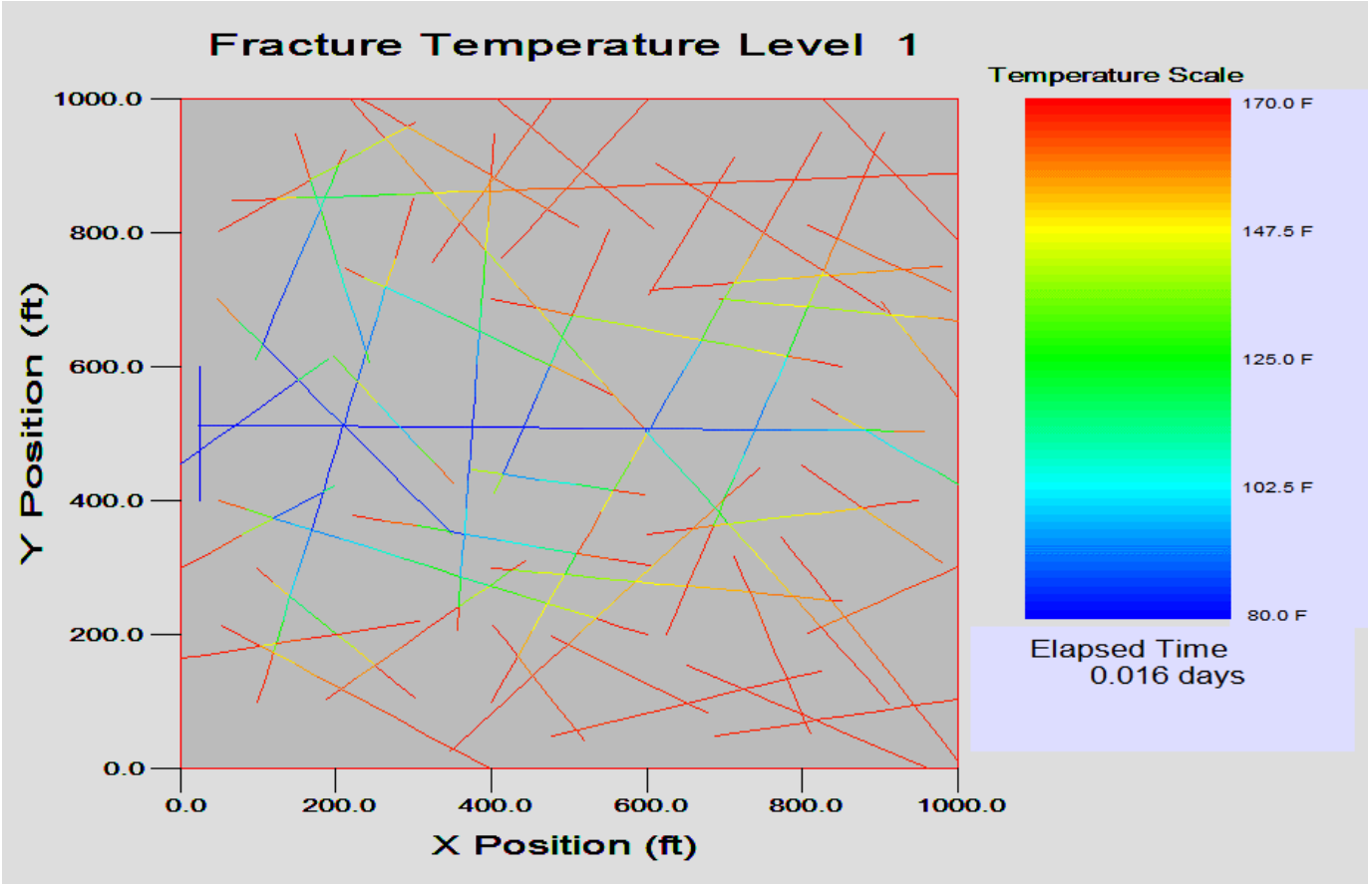


- Mass flux according to Darcy's Law: $\rho\vec{v} = -k_f \frac{\rho}{\mu}\left[\vec{\nabla}P + \rho\vec{g}\right]$
- Mass balance is derived from the continuity equation using the above expression for the mass flux: $\frac{\partial \rho}{\partial t} = -\vec{\nabla} \cdot \frac{k_f}{\mu}\{\rho\left[\vec{\nabla}P + \rho\vec{g}\right]\}$
- Pseudopotential: $\Phi = \int_0^P \frac{f(P',T)}{\mu(P',T)}\,dP'$, where

$$f_{gas} = \frac{P'}{T\,Z(P',T)} \quad \text{or} \quad f_{liquid} = \frac{\rho(P',T)}{\rho_{reference}}$$

- The mass flux is evaluated at the cell boundary using the pseudopotential and uses the boundary temperature: $\frac{\rho}{\mu}\nabla P \propto \nabla\Phi \rightarrow \frac{\Delta\Phi(P,T_b)}{\Delta s}$ where $\Delta\Phi(P,T_b) = \Phi(P_I,T_b) - \Phi(P_J,T_b)$ and where I and J are indices on either side of the boundary.
- The equations are solved sequentially with the mass fluxes first computed and then used in the advection equations,

$$\rho\frac{\partial \hat{u}}{\partial t} + \rho\vec{v}\cdot\vec{\nabla}\hat{u} = \frac{1}{b}(q_L - q_R)$$



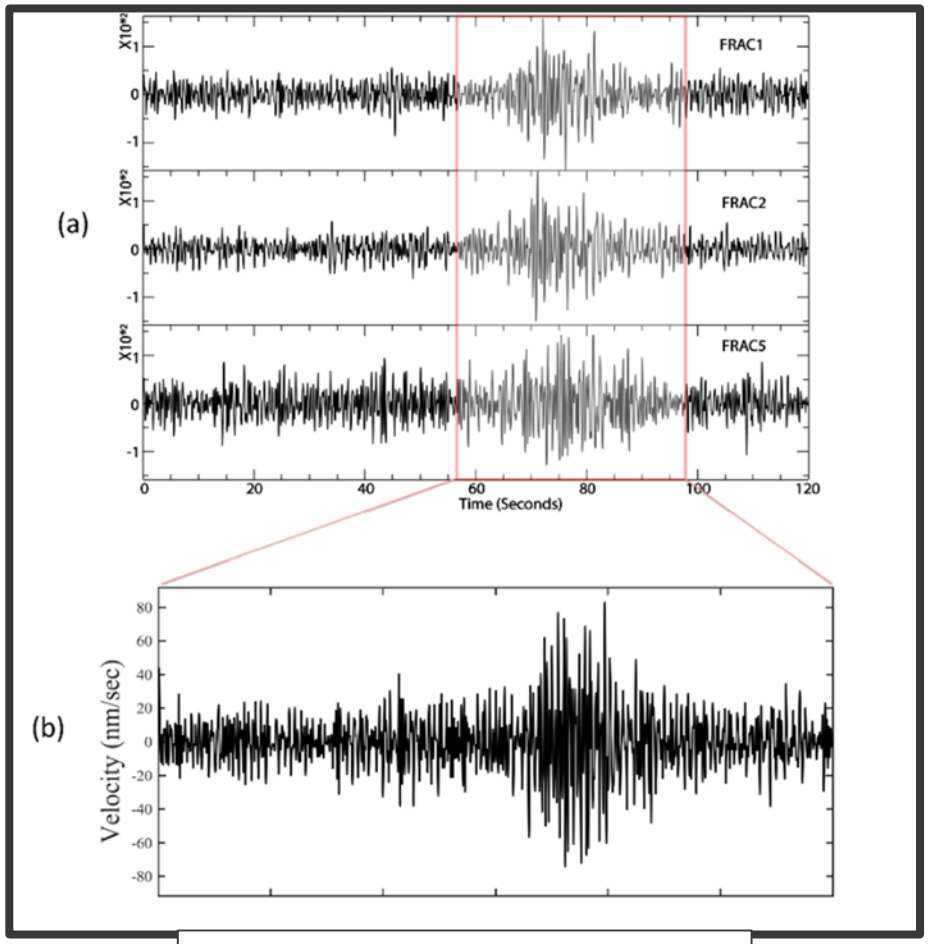
Hydraulic stimulation of hot reservoir w/ cold water

Poster Session – W. Neal Sams

Predict Reservoir Behavior from Geophysical and Geomechanical Attributes – Richard Hammack

Geomechanical & Geophysical Processes Affecting Fracture Behavior & HC Production

- Improved methods for leveraging geophysical signals associated with hydraulic fracturing to **develop a better understanding of monitoring near-well fracture networks and hydrocarbon recovery**

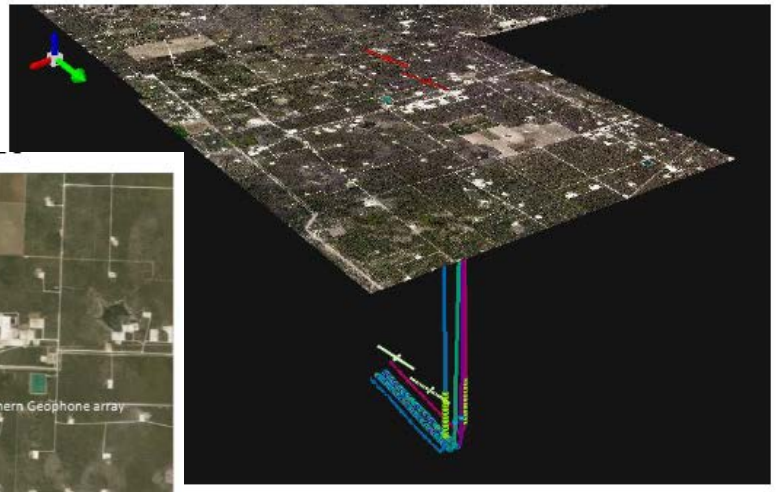


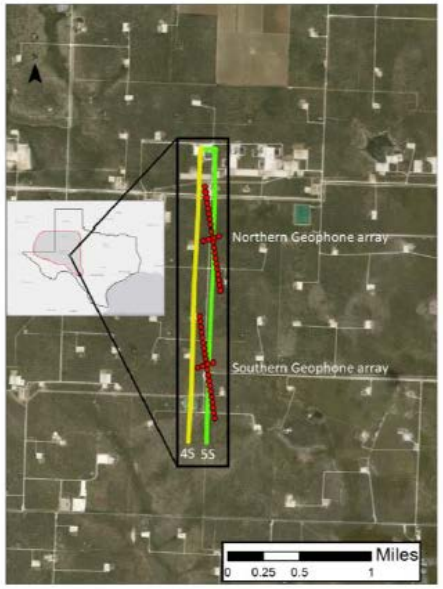
Low Frequency, Long Duration Event

Project Team (NETL): Richard Hammack, Abhash Kumar, David Rampton

Predict Reservoir Behavior from Geophysical and Geomechanical Attributes – Richard Hammack

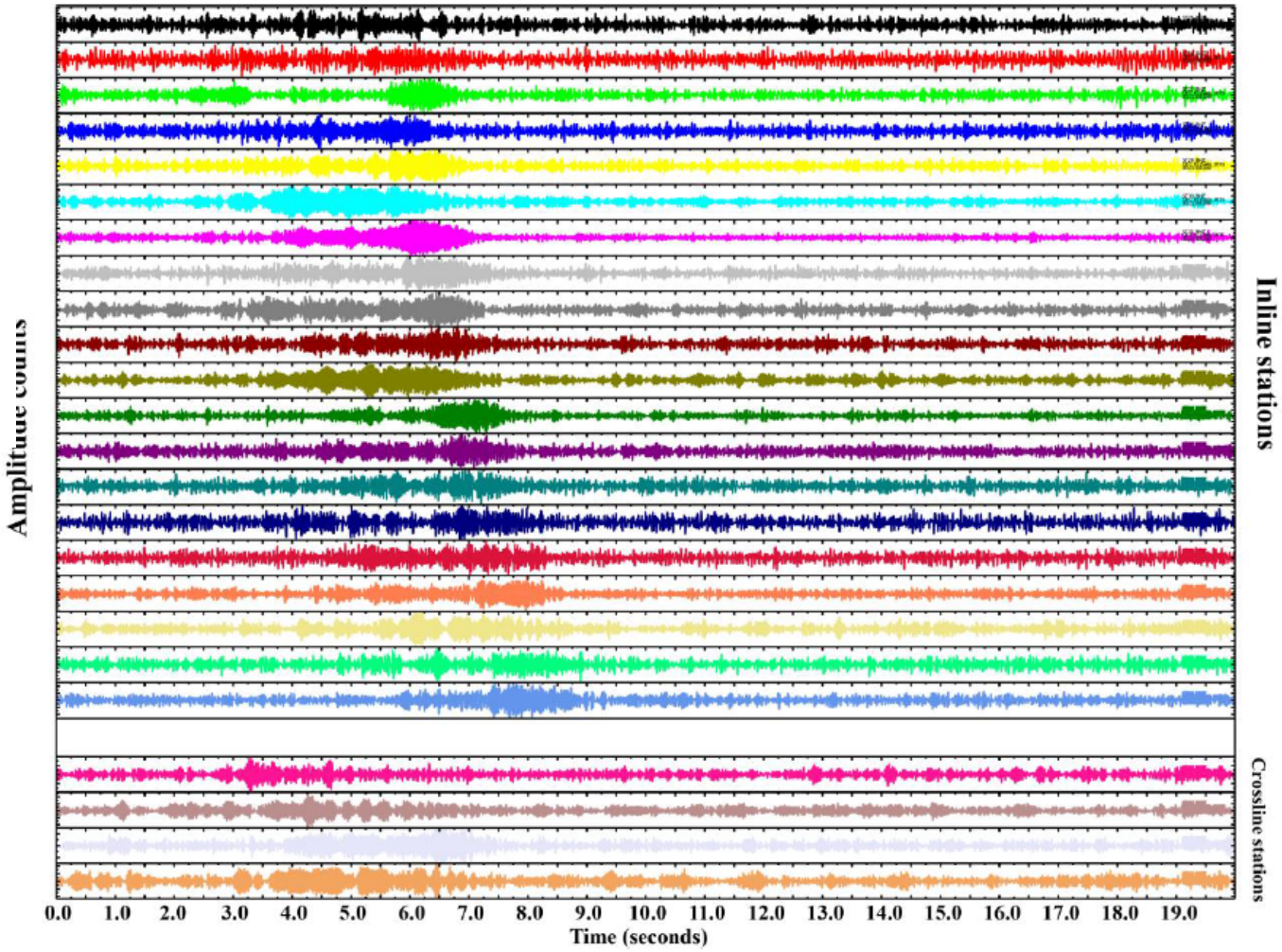
Geomechanical & Geophysical Processes Affecting Fracture Behavior & HC Production





Middle Wolfcamp Shale
Midland Basin (HFTS 1)

LPLD events likely generated in response to tensile opening of cracks triggered by high-pressure fluid injection during hydraulic fracturing



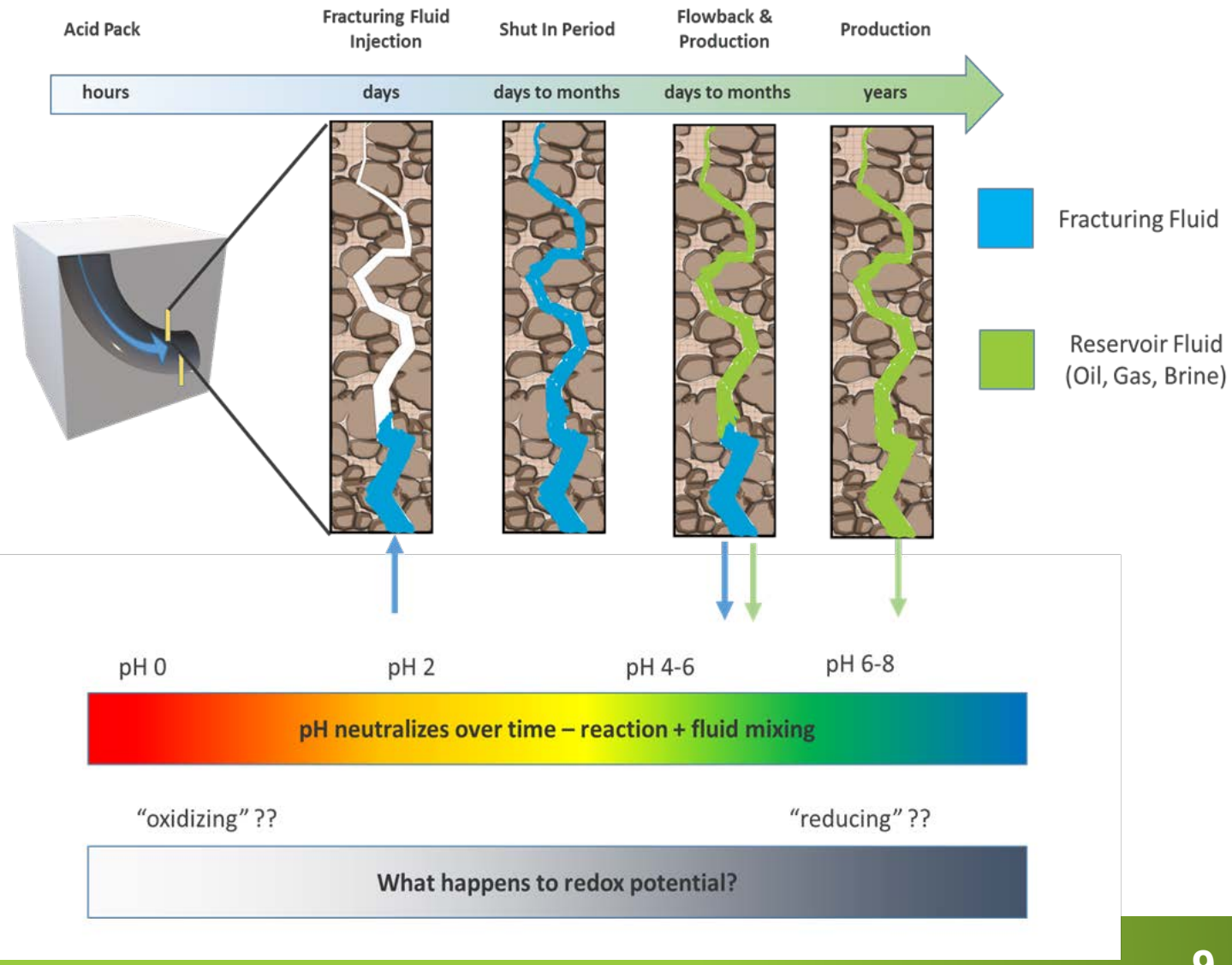
Kumar et al., URTeC, Denver, CO, July 24-26, 2019
Part of the Special Session on Hydraulic Fracture Test Sites

Geochemical Reactions Affecting Reservoir Porosity and Permeability – Alexandra Hakala and Christina Lopano

Geochemical & Biological Processes Affecting Fracture Behavior & HC Production

Poster Session – Brandon McAdams

- **Measurement of how chemical reactions affect hydrocarbon flow pathways** within shale fractures and pores – Redox & organic reactions
- **Distinguishing sources of dissolved constituents in produced waters** that can provide insight on reservoir geochemical reactions that affect matrix and fracture porosity and permeability – Barium isotopes



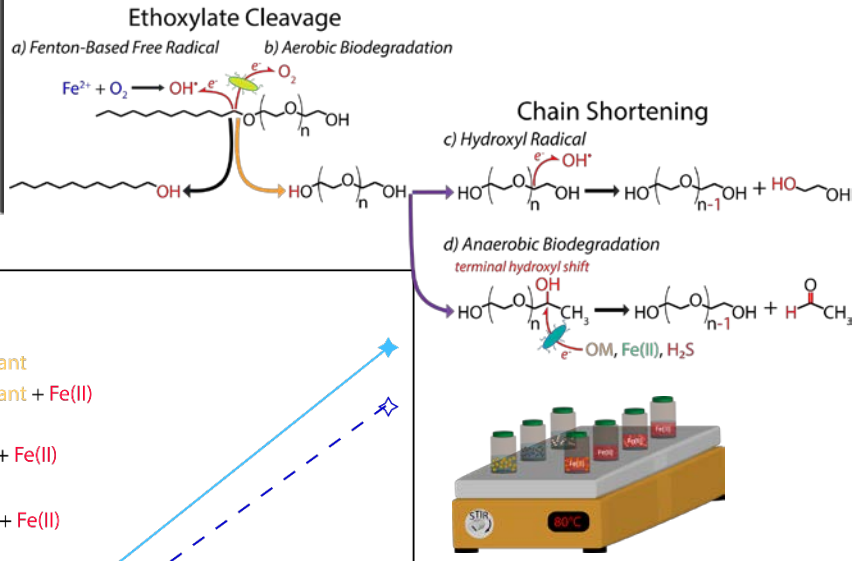
Project Team:

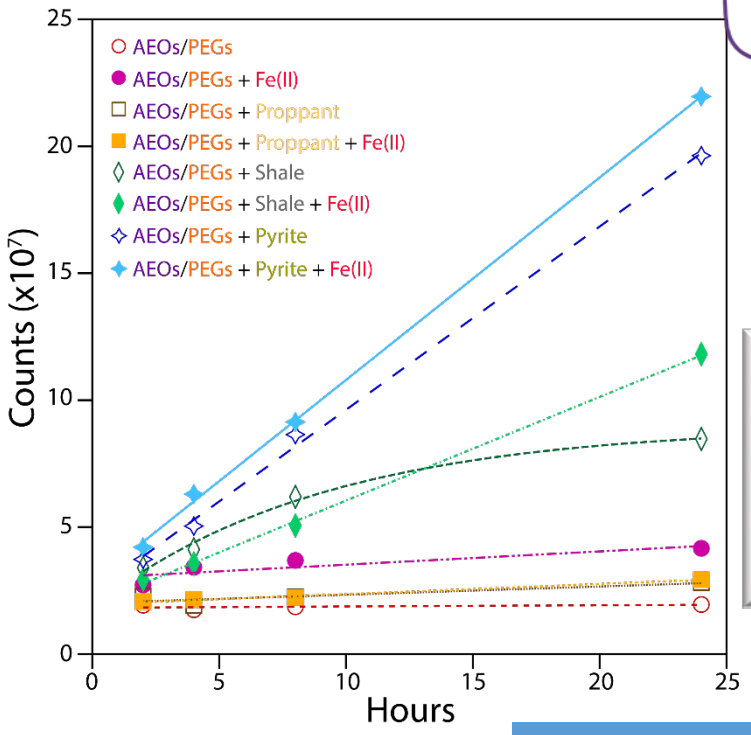
- NETL: Alexandra Hakala, Christina Lopano, Harry Edenborn, Brandon McAdams, Wei Xiong, Robert Thompson, Mengling Stuckman, Johnathan Moore, Bryan Tennant, Lauren Burrows
- University of Pittsburgh: Rosemary Capo, Brian Stewart, Rebecca Matecha
- West Virginia University: Shikha Sharma, Brennan Ferguson

Geochemical Reactions Affecting Reservoir Porosity and Permeability – Alexandra Hakala and Christina Lopano

Geochemical & Biological Processes Affecting Fracture Behavior & HC Production

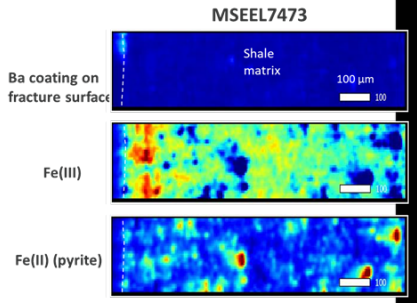
Surfactant structure changes due to reaction with pyrite



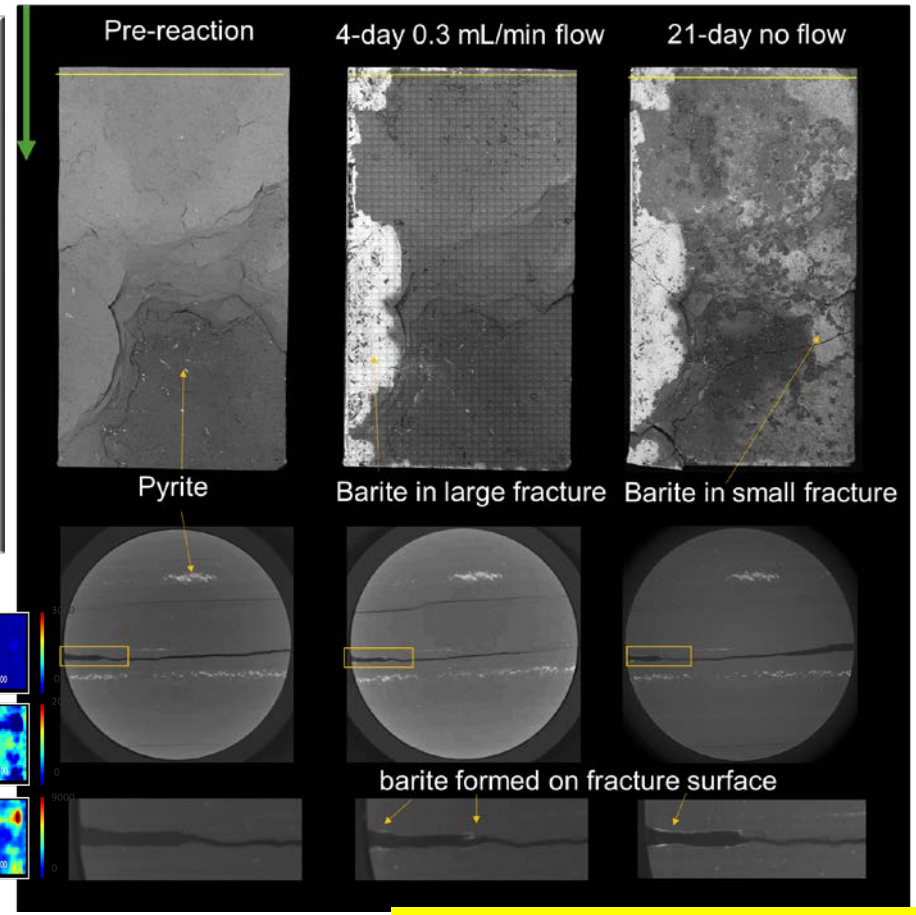


Potential influence on surface wettability in hydraulically-fractured shales

Barite precipitation on shale fracture surfaces is controlled by different processes during injection and shut-in, and **strongly controlled by injected water SO_4^{2-}**



Shale core MSEEL 7473



Poster Session – Christina Lopano

McAdams, Burrows, Hakala, URTeC, Denver, CO, July 24-26, 2019

Xiong et al., American Chemical Society National Meeting, Orlando, FL
Part of session co-organized by SLAC and NETL

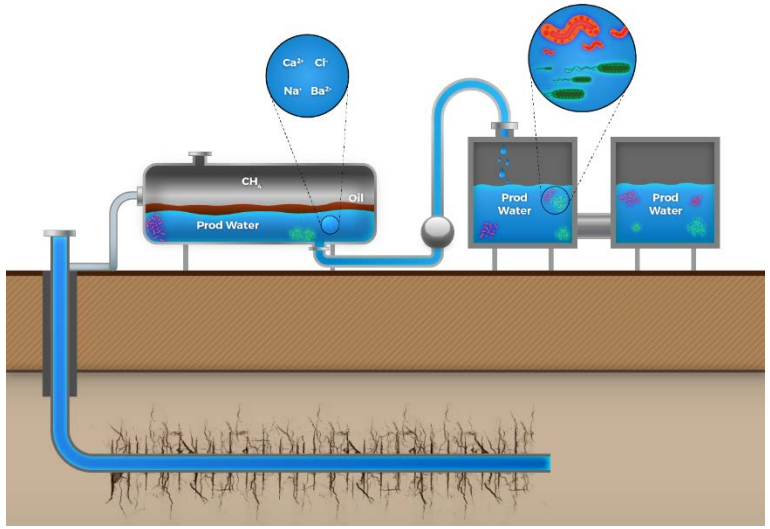
Microbial Ecology of Unconventional Reservoirs – Djuna Gulliver

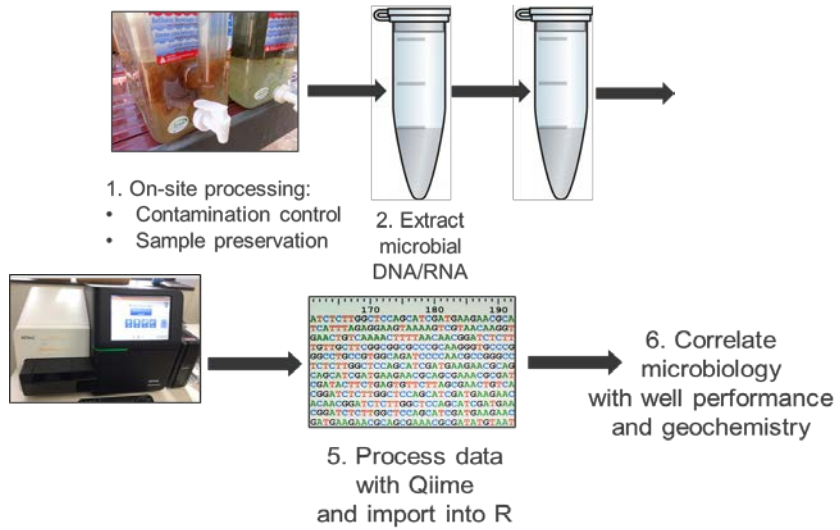
Chemical and Biological Processes Within the Well & Reservoir

- Identification of microbial ecology and biological function within unconventional wells
- Characterize whether DNA is an effective marker for reservoir and well processes

Project Team: Djuna Gulliver, Kara Tinker, Daniel Ross, James Gardiner

- **Survey of industry operating in the Permian** – Microbial ecology within the well is not directly measured; biocide composition is determined based on surface populations; large scale correlation does not yet exist.
- **Prior data from Marcellus wells** – Microbial populations persist in produced water, biocides are not effective, microbiology profiling not being incorporated in well performance diagnostics





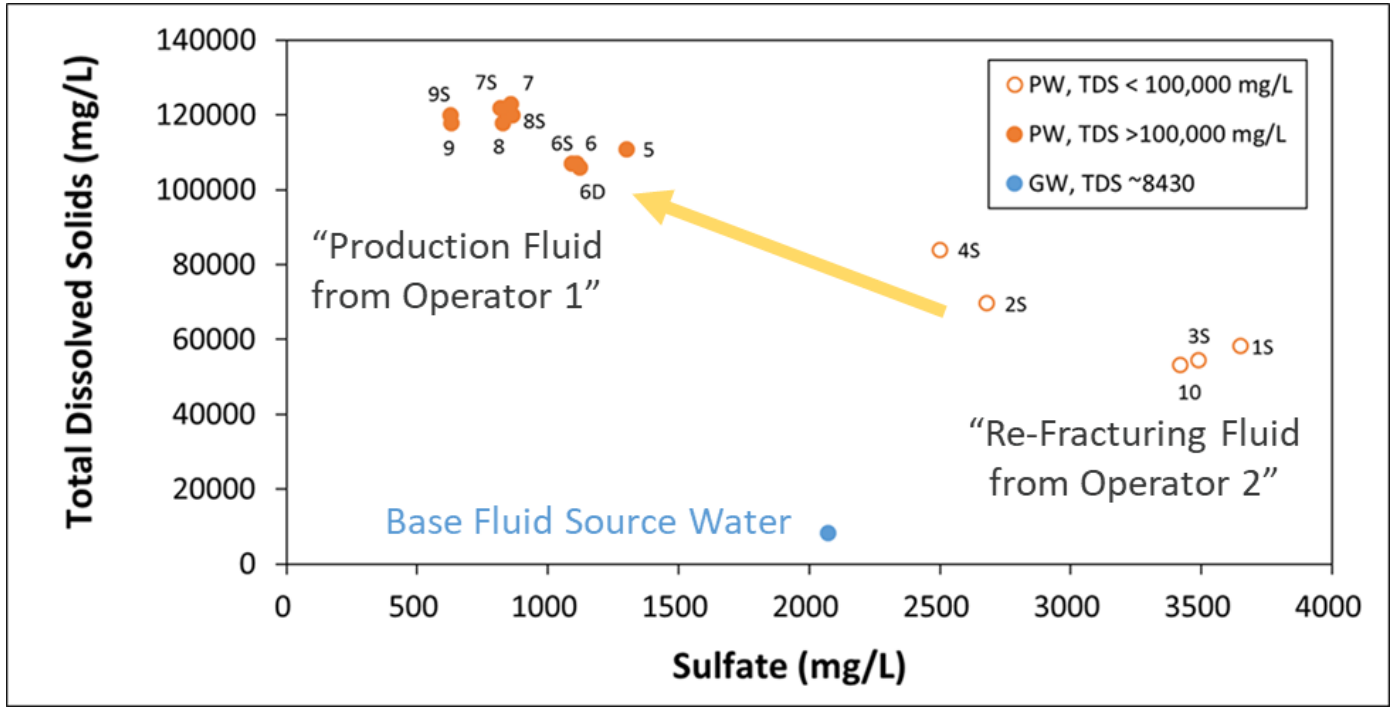
Conference Papers - Sarah Eisenlord (GTI)/Kara Tinker (NETL) – Microbiological Assessment of 3 hydraulically fractured wells at the HFTS (Hydraulic Fracture Test Site), Permian – 7th International Symposium on Applied Microbiology and Molecular Biology in Oil Systems, Halifax, Nova Scotia, Canada, June 18-21, 2019

Microbial Ecology of Unconventional Reservoirs – Djuna Gulliver

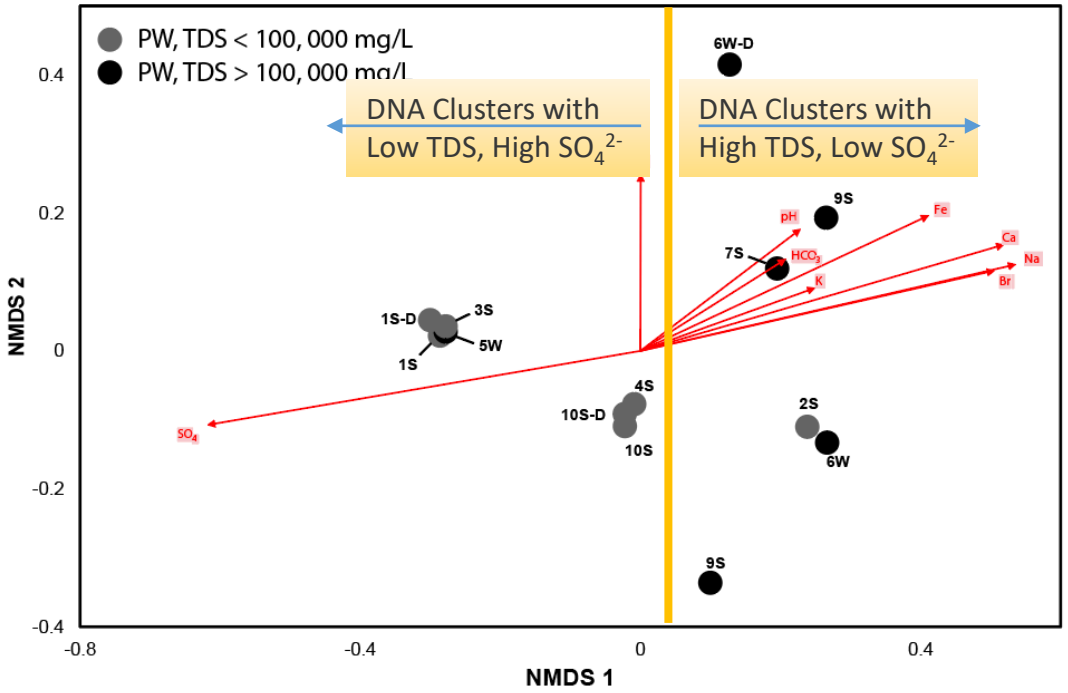
Chemical and Biological Processes Within the Well & Reservoir

Well Chemistry Shows Influence of Adjacent Well Activity

Not Influenced by Base Fluid Source Water Composition



Statistical Analysis Shows that Chemistry and Microbiology are Related in Unconventional Reservoirs



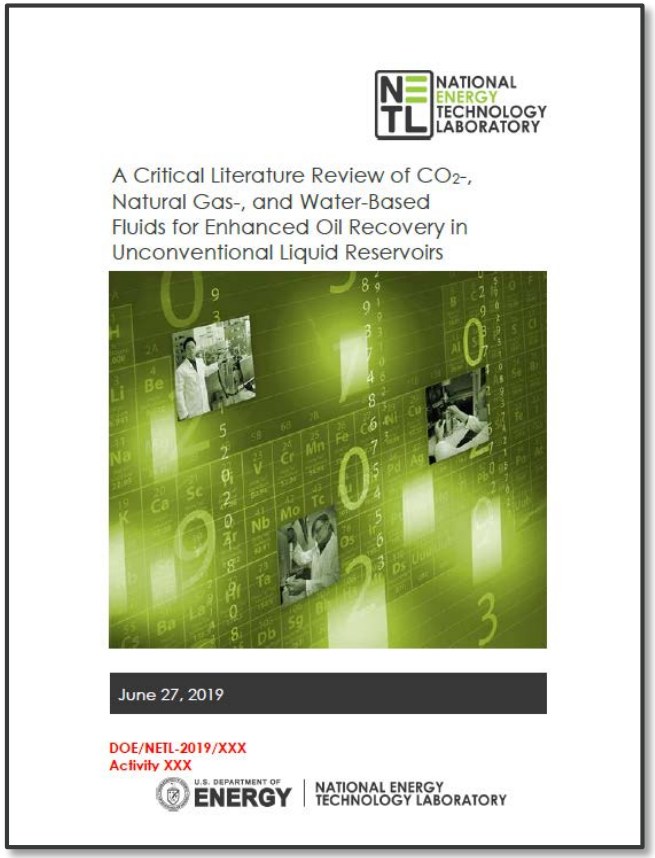
Poster Session – Djuna Gulliver

Characterizing Application of CO_2 as a Recovery Agent to Mobilize Hydrocarbons from Shale – Angela Goodman

Geochemical & Biological Processes Affecting Fracture Behavior & HC Production

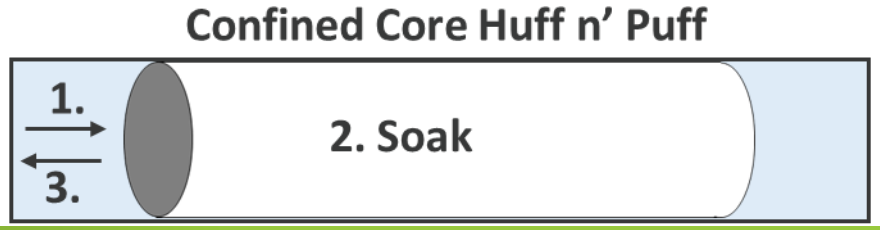
➢ Quantifying enhanced oil recovery with CO_2 to optimize oil production

- Completed an extensive NETL report EOR in Unconventional Reservoirs
- Concluded that ***both*** CO_2 and natural gas are viable gases for EOR
- Experiments will focus on CO_2 EOR in shale cores.
- Work will complement the work focused on Natural Gas EOR



Poster Session – Angela Goodman

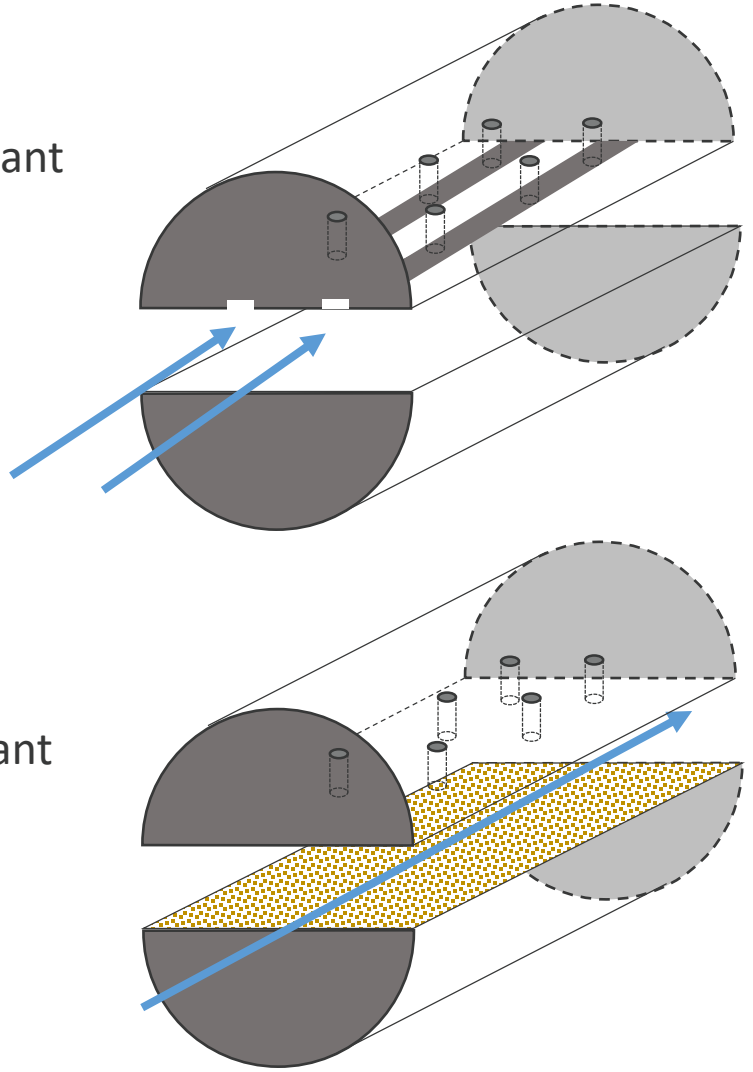
<u>Seeking industry partnerships to help obtain oil-saturated "at-depth" shale cores</u><u>, which will improve the reliability of our laboratory-scale experiments – HFTS 1 EOR</u>



Advanced Modeling Project – Alexandra Hakala, Christina Lopano, Dustin Crandall

Geochemical & Biological Processes Affecting Fracture Behavior & HC Production

- Part of LBNL-LLNL-SLAC-NETL effort on "A New Framework for Microscopic to Reservoir-Scale Simulation of Hydraulic Fracturing and Production: Testing with Comprehensive Data from HFTS and other Hydraulic Fracturing Field Test Sites

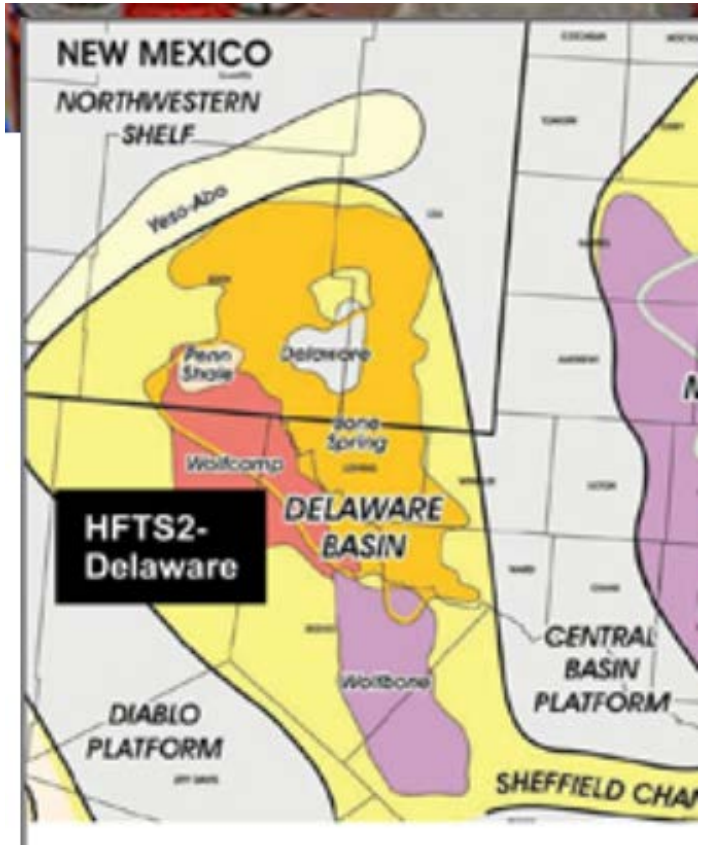


Jens Birkholzer (LBNL) & Joe Morris (LLNL)
Tuesday, 4:40 PM, Rooms 301,302

Geochemical Studies in Support of HFTS II – Alexandra Hakala, Christina Lopano, Djuna Gulliver

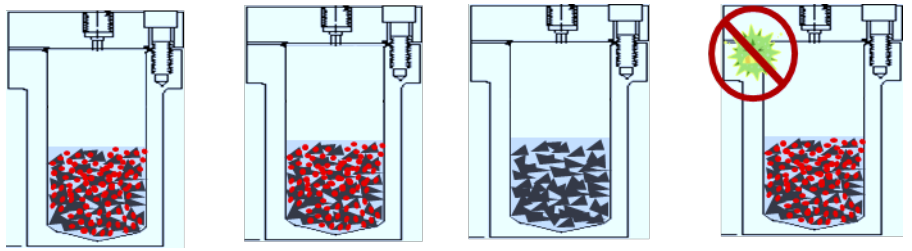
Geochemical & Biological Processes Affecting Fracture Behavior & HC Production

Characterizing biogeochemical reactions affecting sulfide production



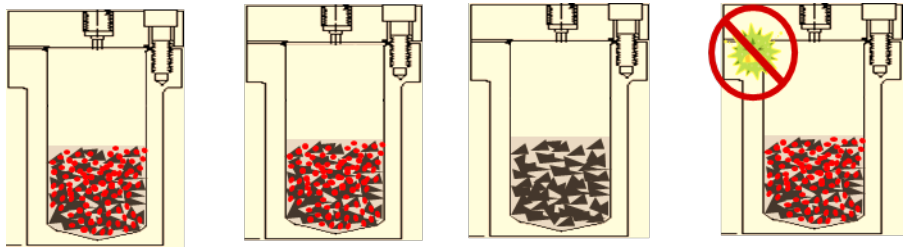
Production Lower P,T Condition Experiments - GTI

Expect biological reactions to control chemistry



Reservoir Shut-In Condition Experiments - NETL

Expect abiotic reactions to control chemistry



Project Team:

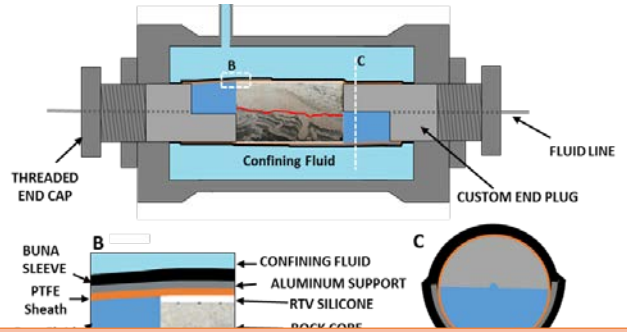
- NETL: Alexandra Hakala, Christina Lopano, Djuna Gulliver
- GTI: Sarah Eisenlord, Jordan Ciezboka, Brian Landreth, Karen Crippen, Amanda Harmon

Fundamental Processes for Unconventional Formations

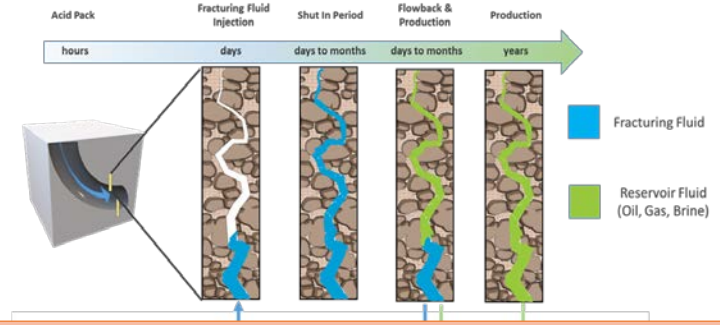
Identification of reservoir-based processes that impact hydrocarbon production

NATIONAL ENERGY TECHNOLOGY LABORATORY

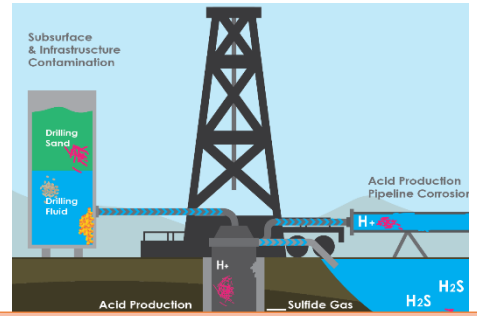
Geomechanics



Geochemistry

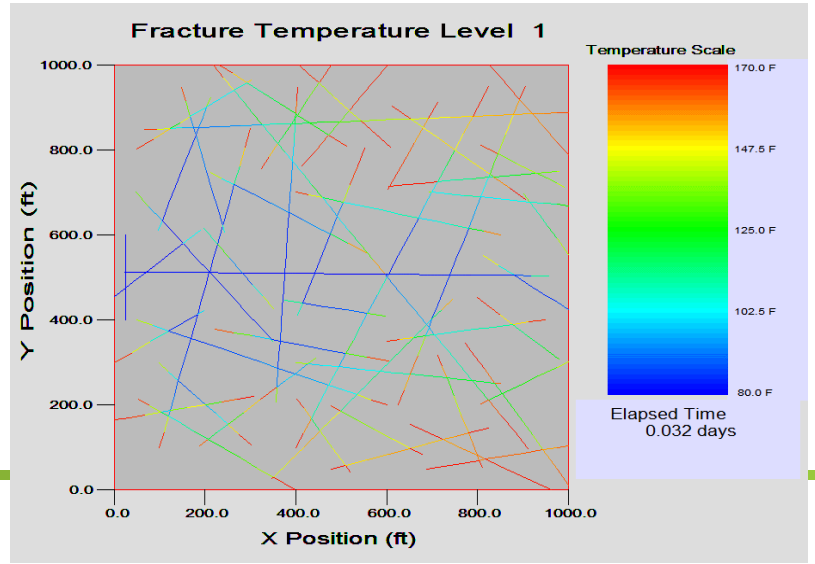


Geobiology



Questions?

Fracture Modeling



Geophysics