The Eagle Ford Shale Laboratory: A Field Study of the Stimulated Reservoir Volume, Detailed Fracture Characteristics, and EOR Potential

Award No. DE-FE0031579

Texas A&M University

Lawrence Berkeley National Laboratory

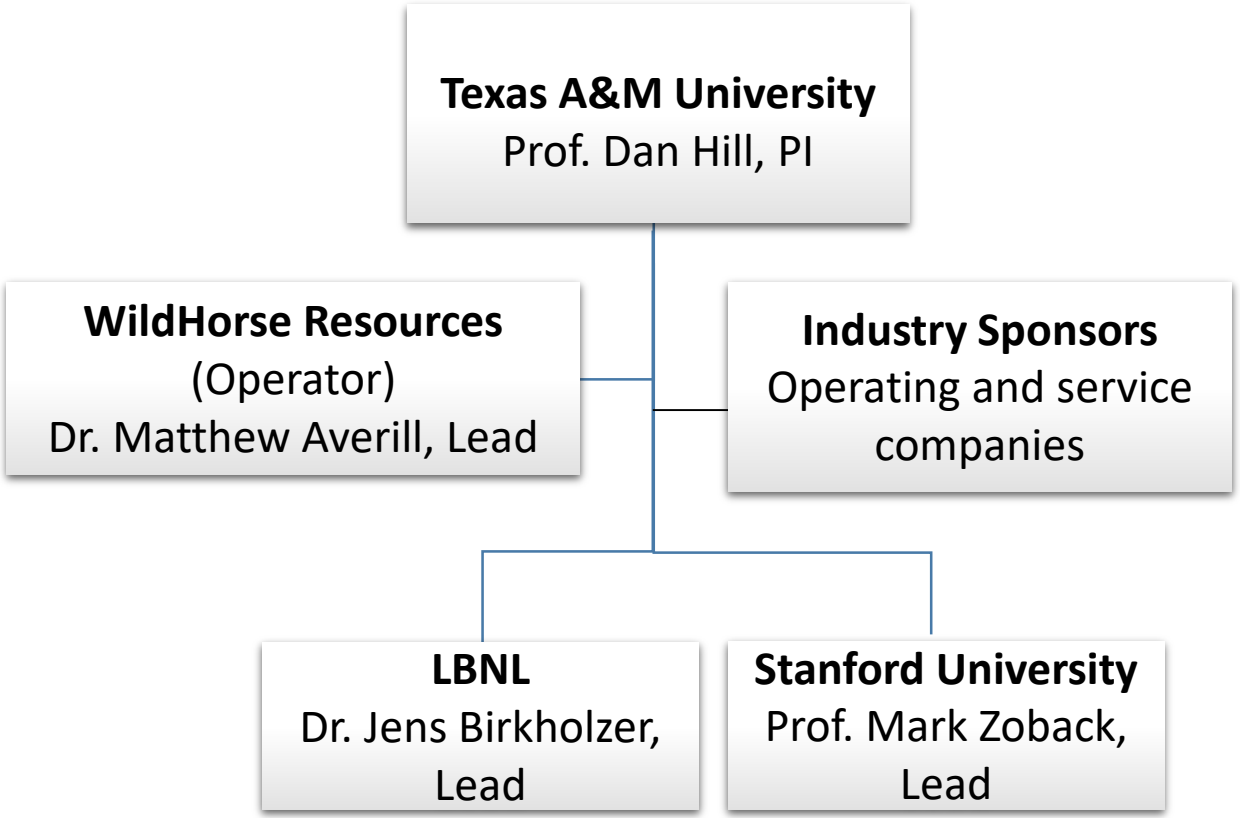
WildHorse Resource Development

Stanford University

Eagle Ford Shale Laboratory (EFSL)

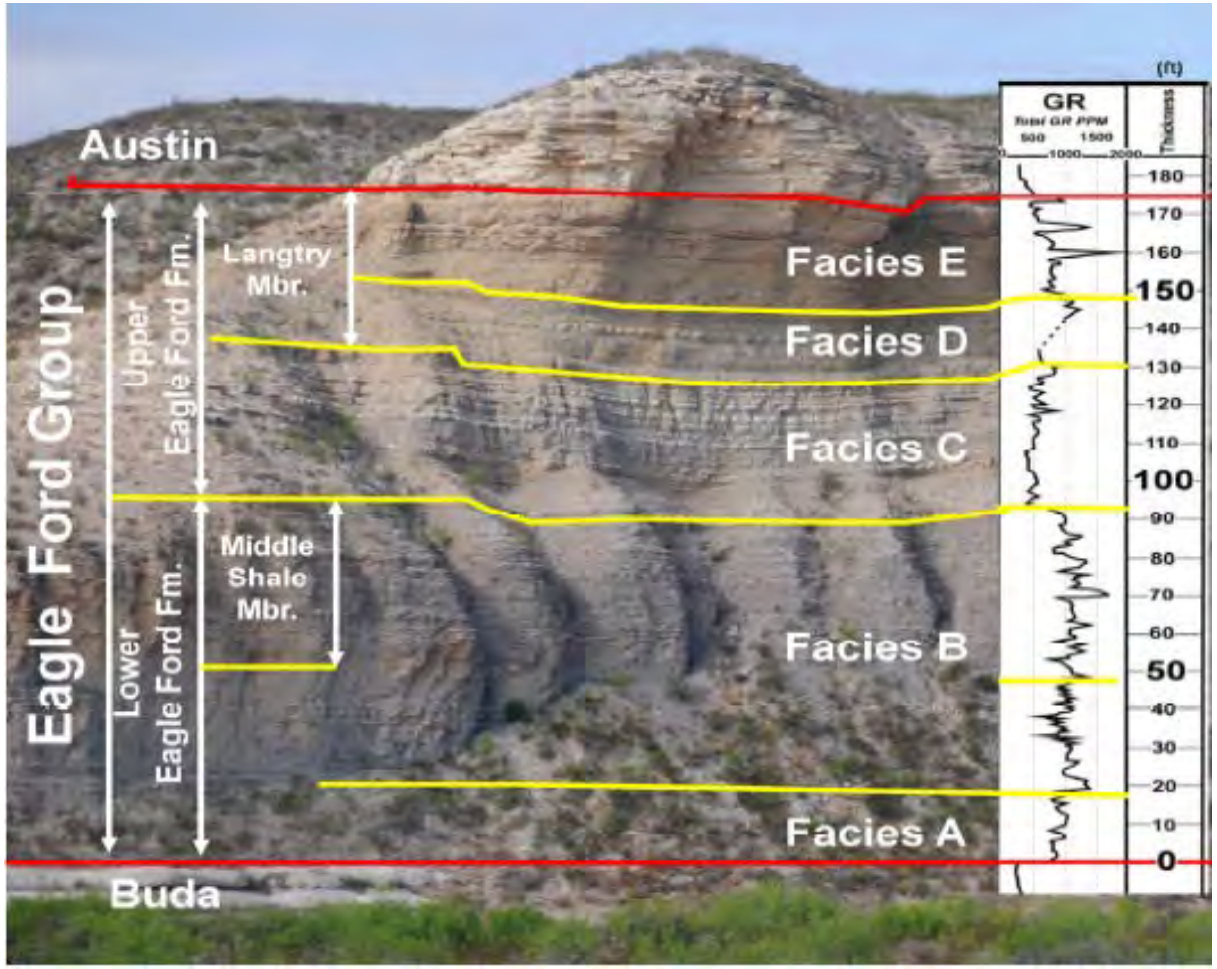
- Research Team:
  - **Texas A&M University**
  - Lawrence Berkeley National Lab
  - Stanford University
- Operator: WildHorse Resource Development
- Field Site: Eagle Ford Shale near Caldwell, TX
- Project Period: 04/01/2018 – 03/31/2021

Project Teams



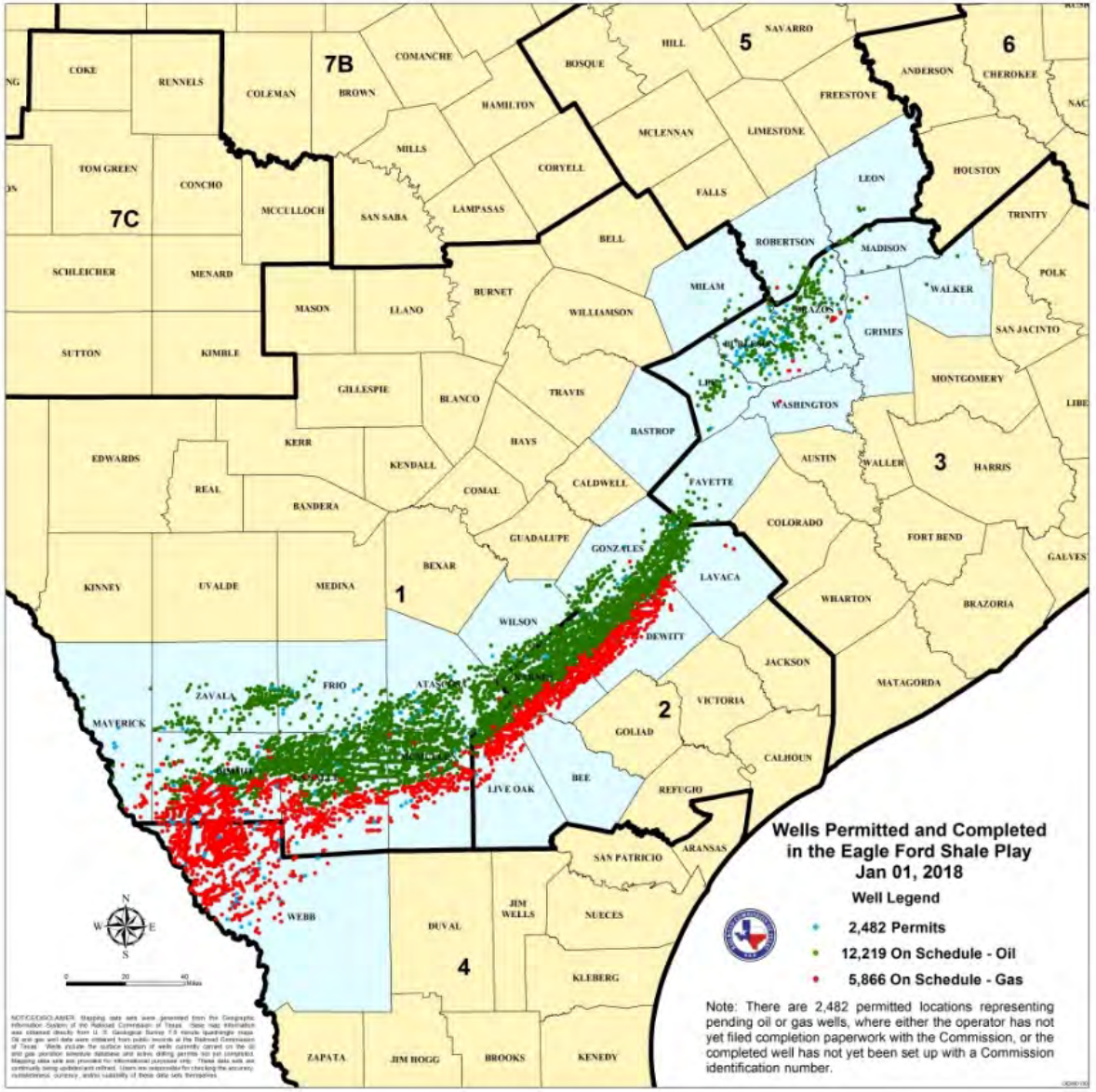
- **Texas A&M University**
  - **Dan Hill** (lead PI for the project)
  - **Ding Zhu** (Fracture Monitoring)
  - **George Moridis** (Fracture Modeling)
  - **David Schechter** (EOR)
  - **Dante Guerra** (Program Manager)
- **WildHorse Resource Development**
  - **Matthew Averill** (WRD lead)
- **Lawrence Berkeley National Laboratory**
  - **Jens Birkholzer** (LBNL lead)
  - **Kurt Nihei** (Geophysicist)
  - **Jonathon Ajo-Franklin** (Active Seismic)
- **Stanford University**
  - **Mark Zoback** (Stanford lead)

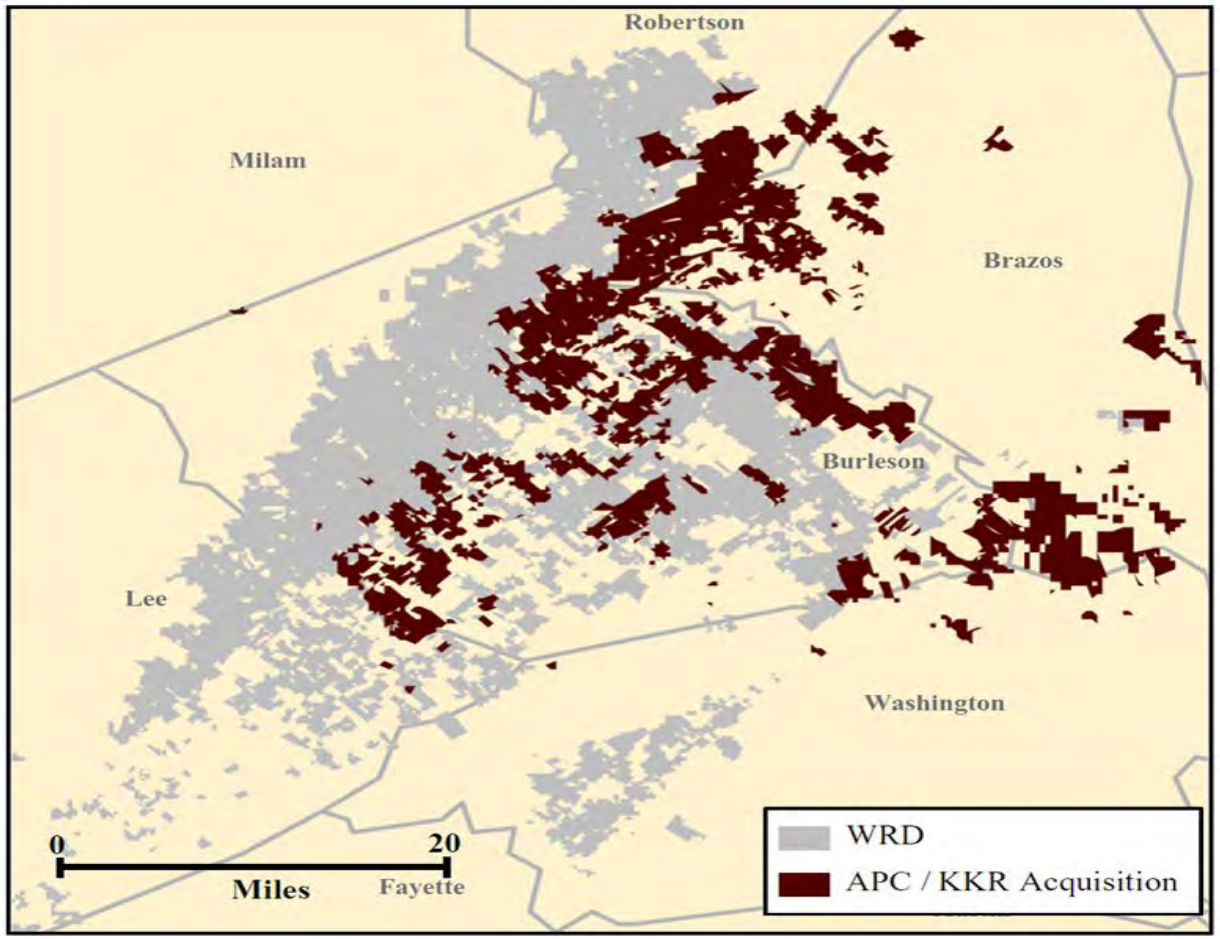
Eagle Ford Shale



Oil production: >1,400,000 bopd, gas:>7 Bcf/d

Eagle Ford Shale





WildHorse Properties

Objectives of the Project

1. Perform high-spatial and -temporal resolution active and passive monitoring to image the stimulated reservoir volume (SRV) during fracturing, re-fracturing and gas-EOR processes.
2. Monitor long-term production (inflow profiles and bottomhole pressures) in producing and observation wells
3. Improve drilling efficiency
4. Optimize the fracturing process
5. Evaluate EOR in the field
6. Calibrate fracture/reservoir models

EFSL Main Tasks

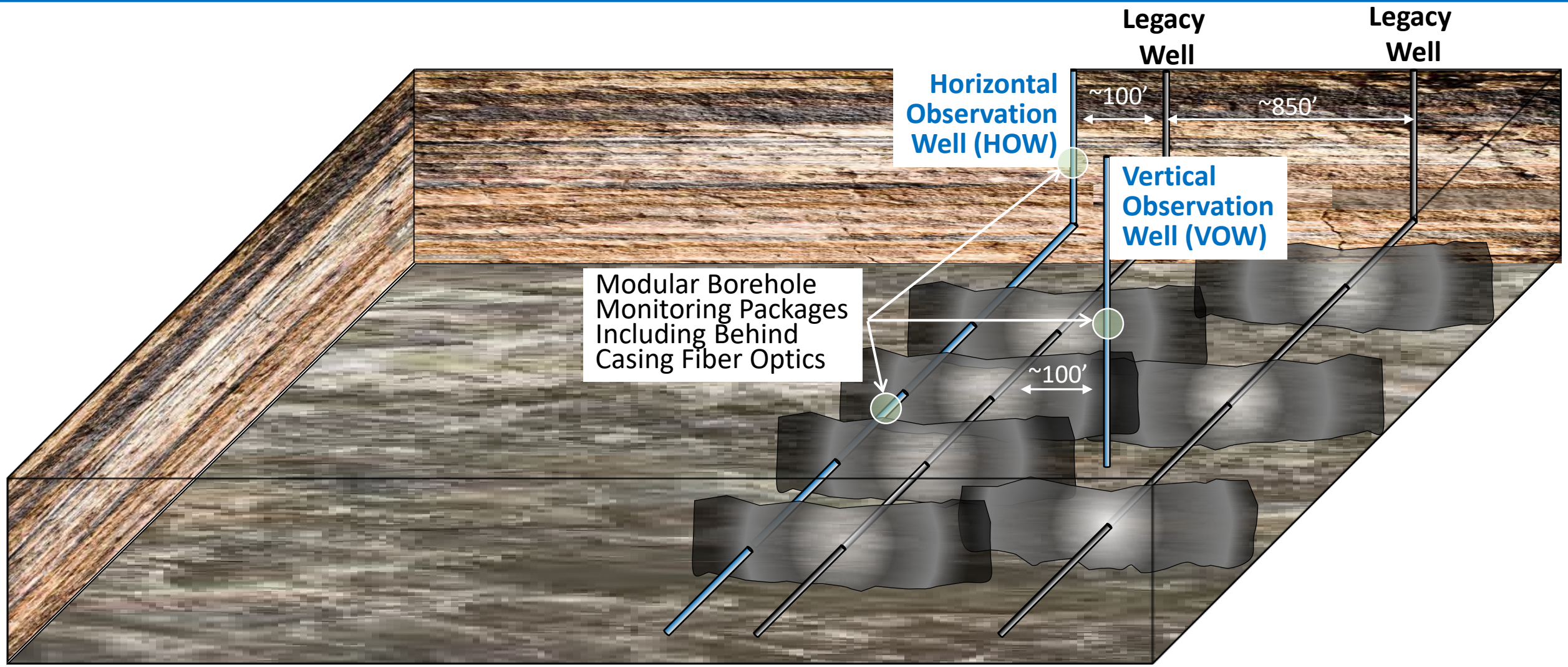
- Phase I : Re-fracture monitoring and evaluation
- Phase II: Monitoring, evaluation and optimization of multistage fracture stimulation (two new producers)
- Phase III: EOR pilot with gas injection

Advanced Technologies

Extensive, robust, state-of-art monitoring, diagnosing and modeling abilities:

- Geosteering and Thru-bit monitoring during drilling
- Active seismic interrogation
- Permanent fiber optic sensing (DTS, DAS, DSS)
- Extensive logging for formation evaluation and fracture diagnosis
- Tracer evaluation of re-frac
- Vertical well cores for supporting lab work
- Theoretical and numerical modeling

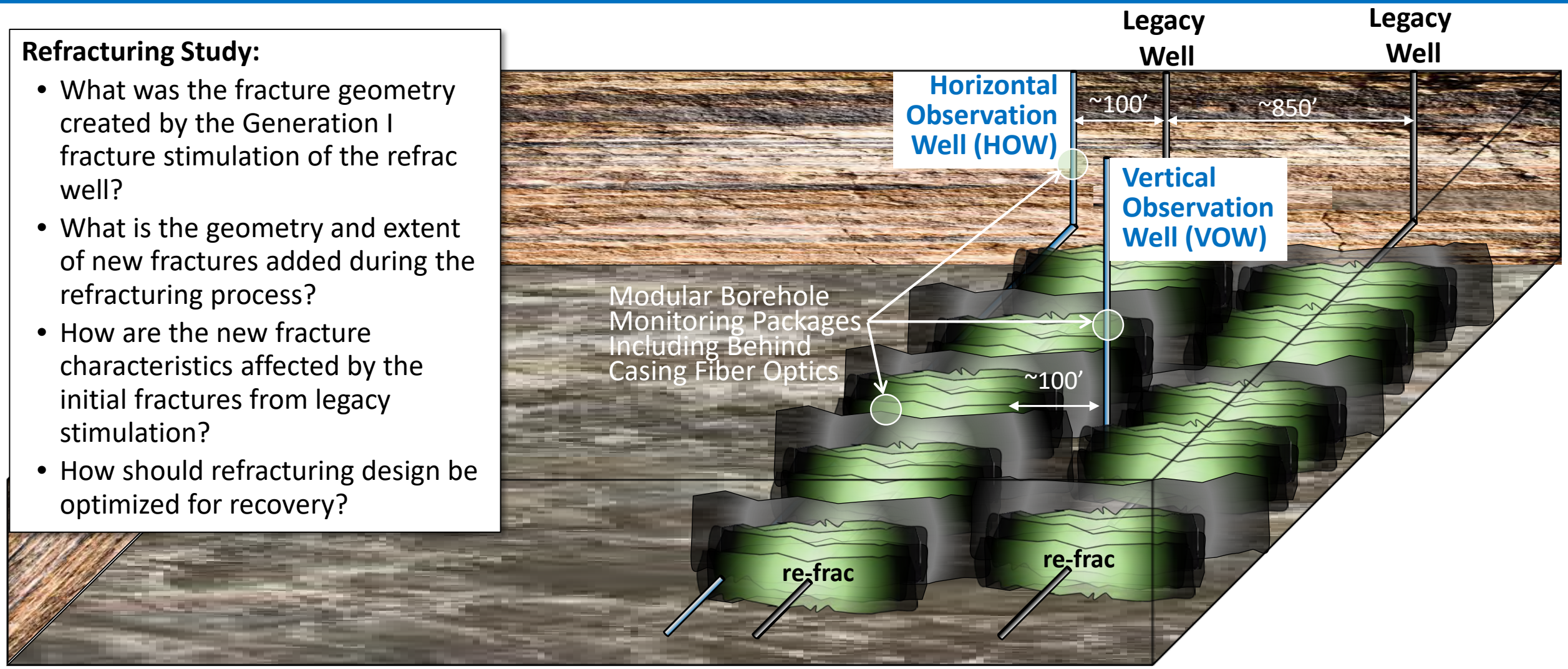
Observation Wells



Field Plan: Phase I - Refracture Study

Refracturing Study:

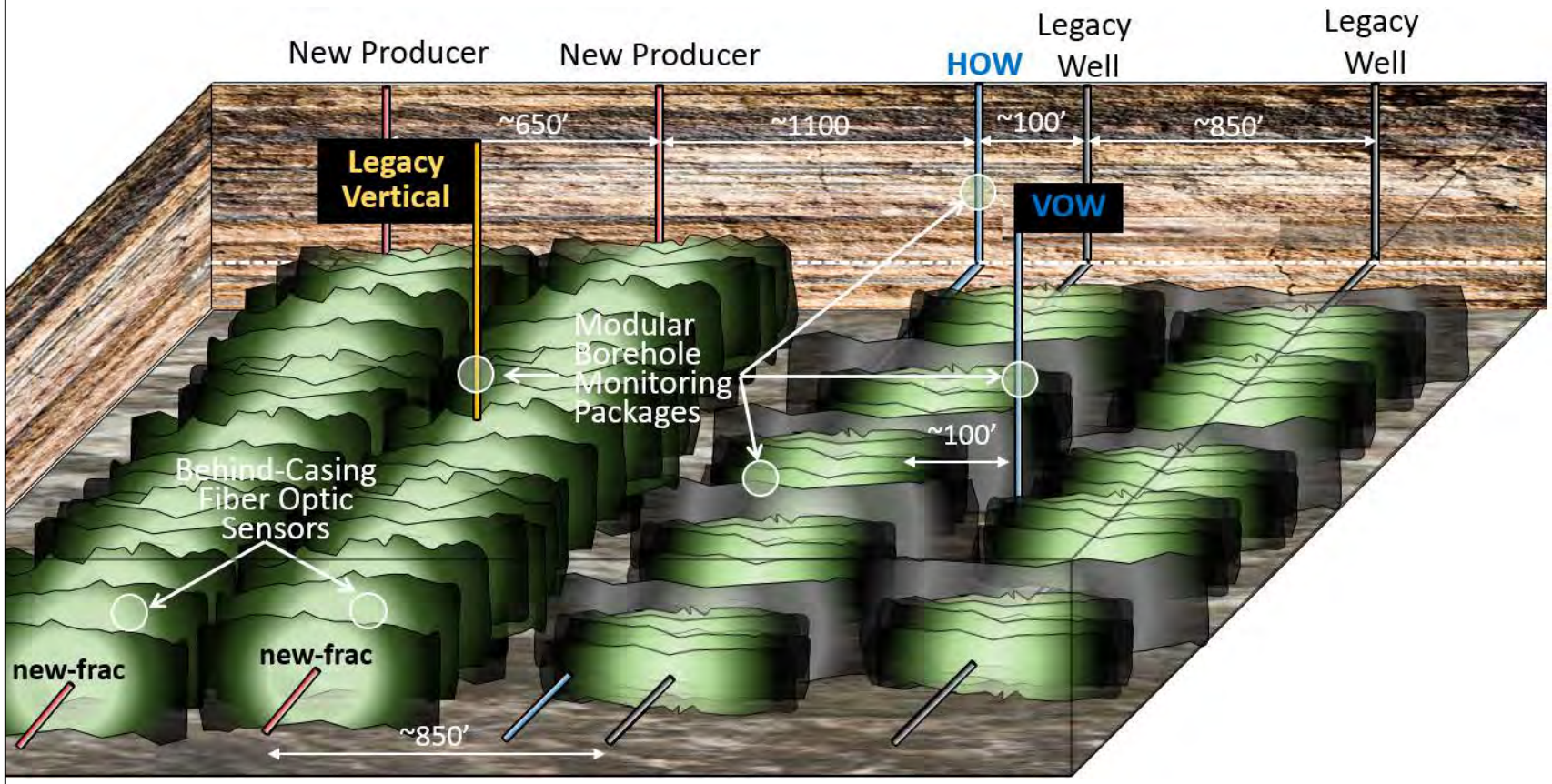
- What was the fracture geometry created by the Generation I fracture stimulation of the refrac well?
- What is the geometry and extent of new fractures added during the refracturing process?
- How are the new fracture characteristics affected by the initial fractures from legacy stimulation?
- How should refracturing design be optimized for recovery?



Field Plan: Phase II - Fracture Study

Fracture Study:

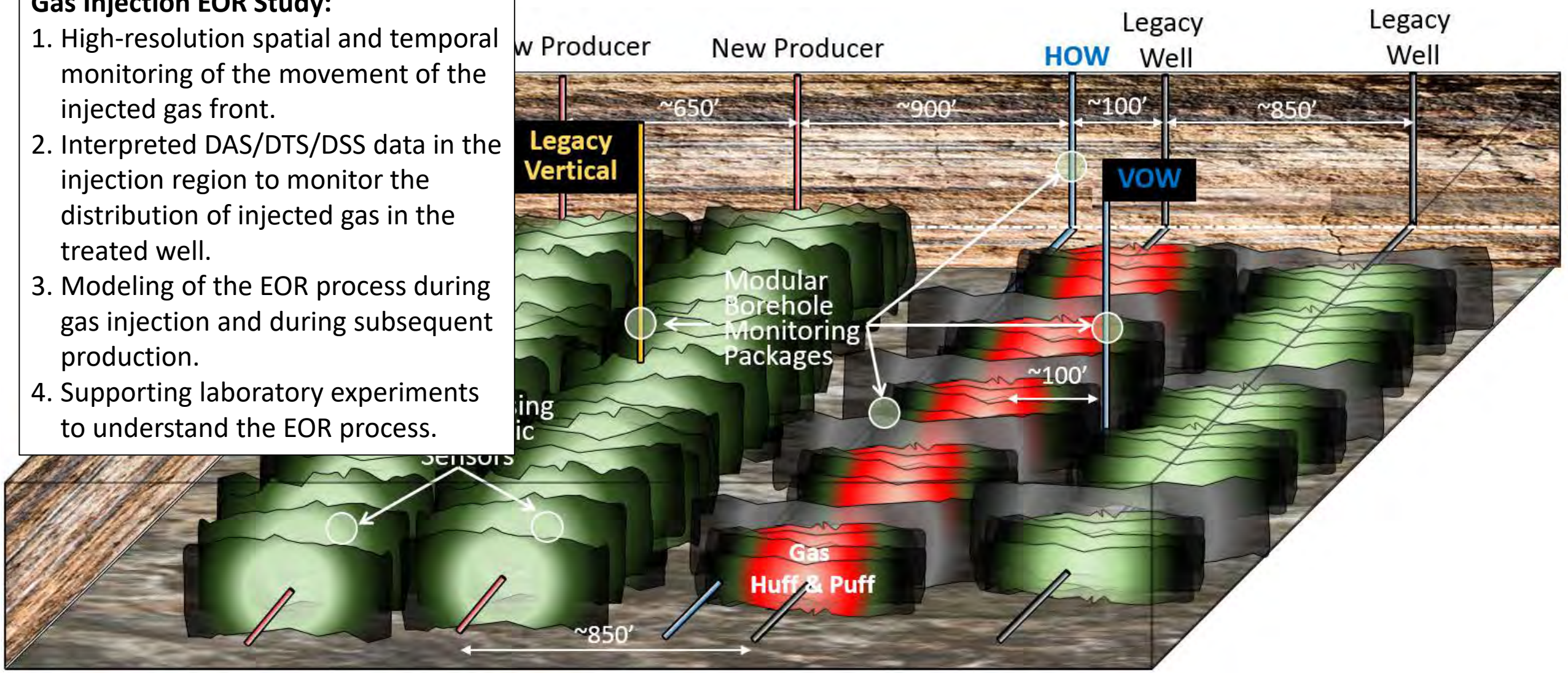
1. Optimization of drilling practices in the Eagle Ford shale.
2. Analysis and improvement of Eagle Ford targeting.
3. Laboratory methods to evaluate drill cuttings to serve as a well log proxy.
4. Mapping of created fracture geometry using active seismic monitoring and DAS/DTS/DSS technologies.
5. Evaluation of post-fracturing production performance by continuous monitoring of DAS/DTS/DSS responses and downhole pressure gauges.
6. Calibration of advanced reservoir and fracture models using all monitored data.



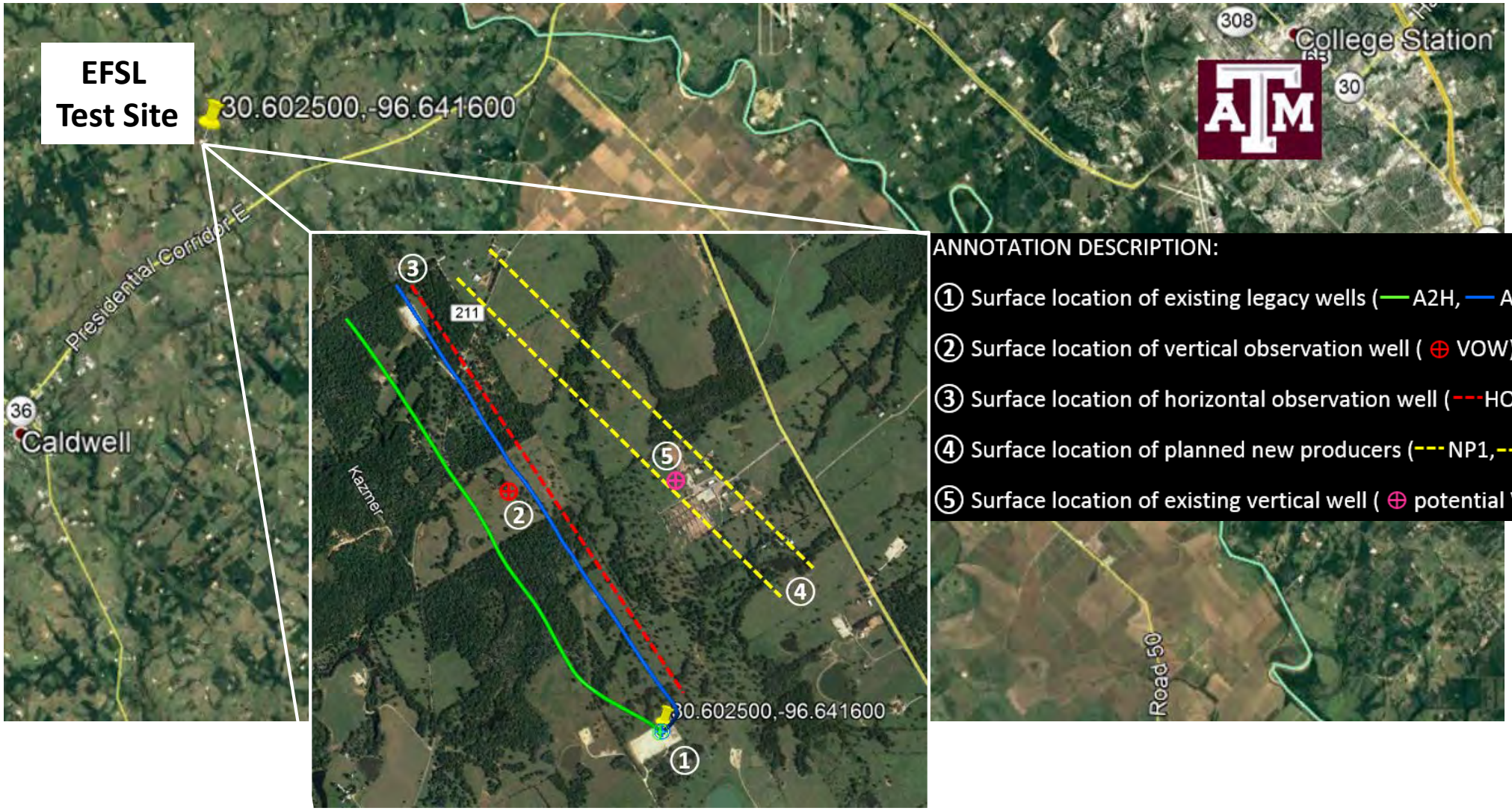
Field Plan: Phase III – Gas EOR Study

Gas Injection EOR Study:

1. High-resolution spatial and temporal monitoring of the movement of the injected gas front.
2. Interpreted DAS/DTS/DSS data in the injection region to monitor the distribution of injected gas in the treated well.
3. Modeling of the EOR process during gas injection and during subsequent production.
4. Supporting laboratory experiments to understand the EOR process.



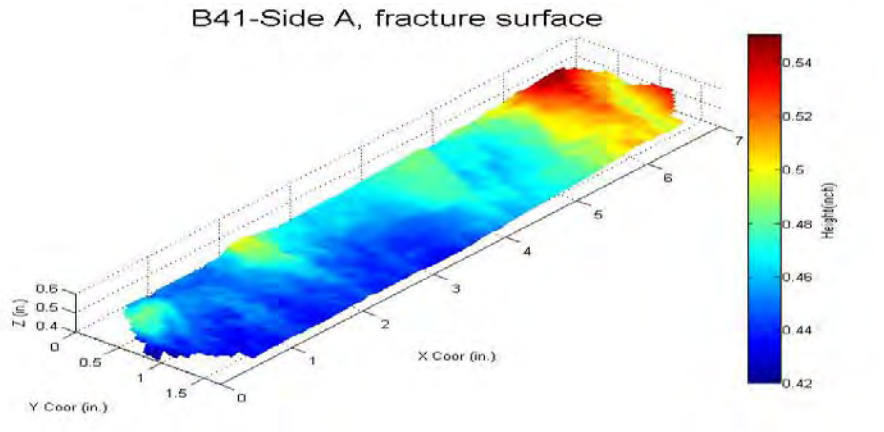
EFSL Test Site Location

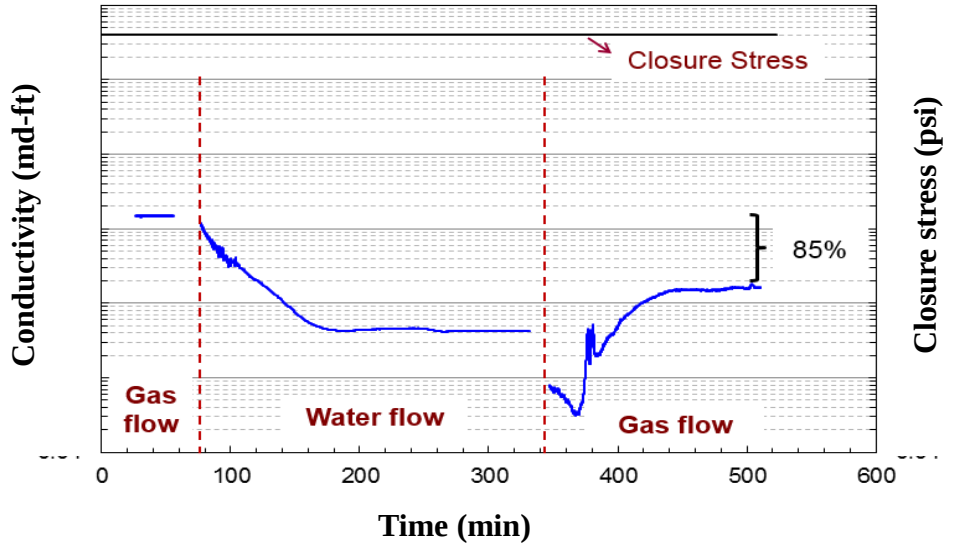


Research Team:
Texas A&M University

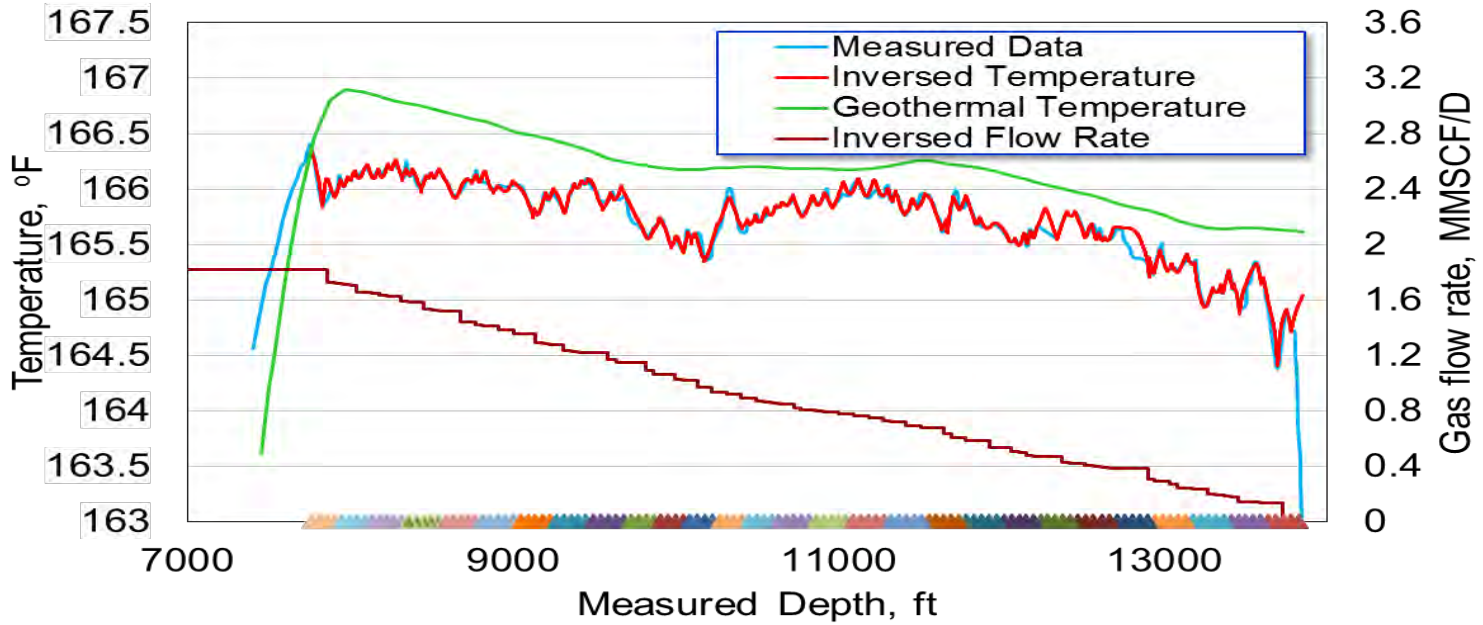
- Overall project management
- DTS/DAS interpretation
- Lab testing of fracture conductivity using cores
- Drilling performance monitoring and optimization
- Rock property measurements using drill cuttings
- Fracture/reservoir modeling and calibration
- Lab testing of gas injection EOR processes
- EOR pilot design

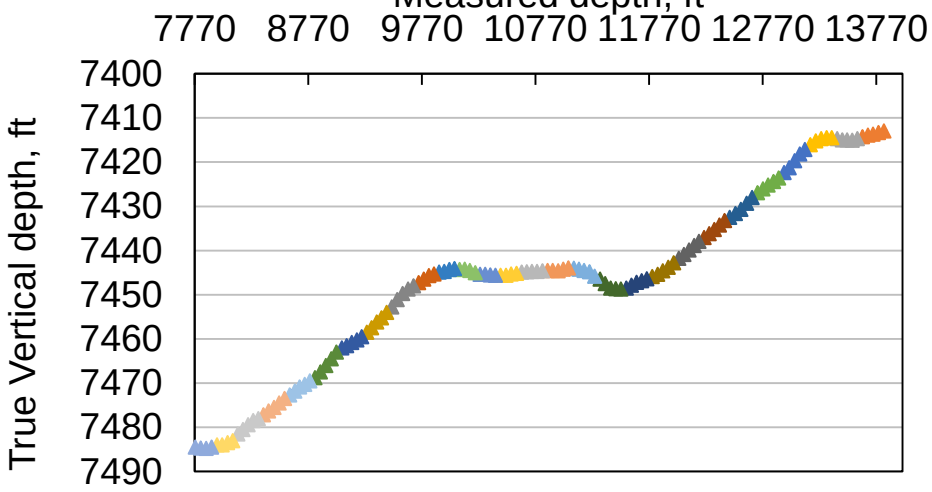
TAMU Research: Conductivity Study

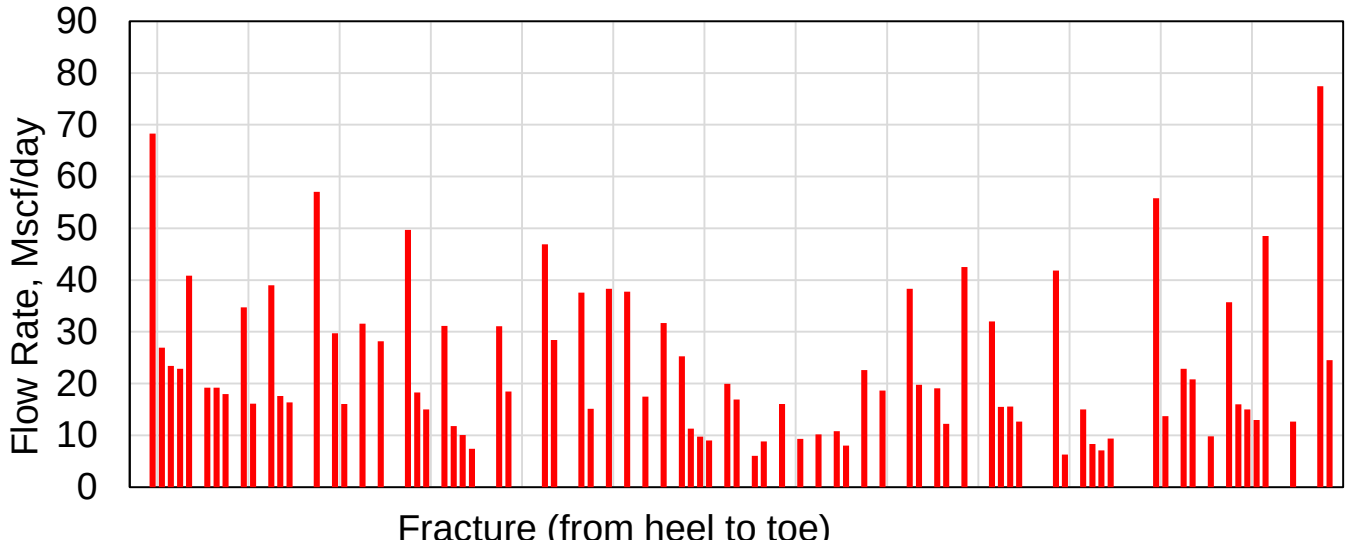




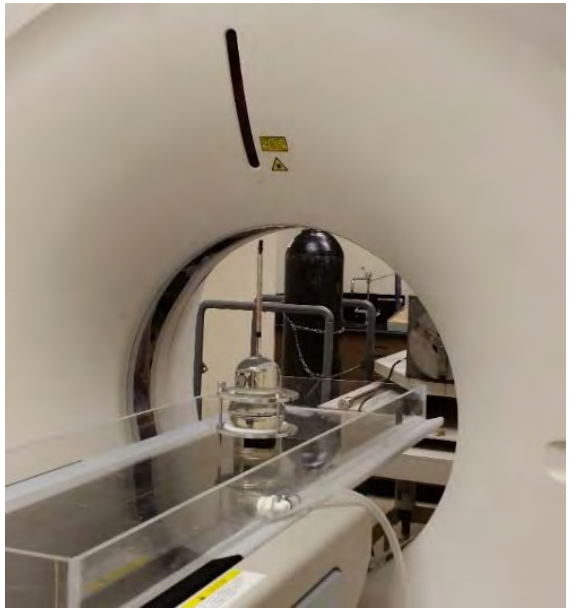
TAMU Research: DTS Interpretation

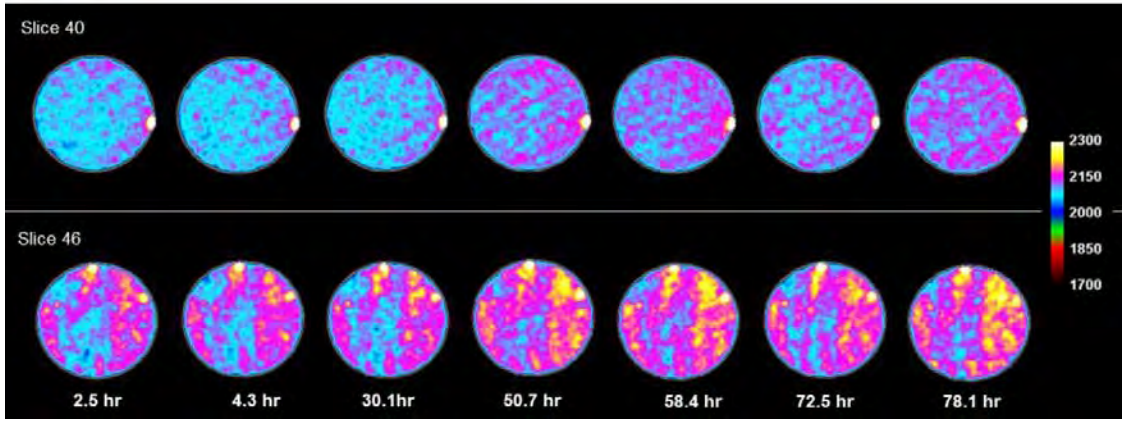


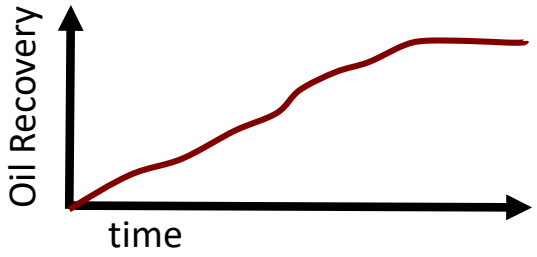




TAMU Research: EOR

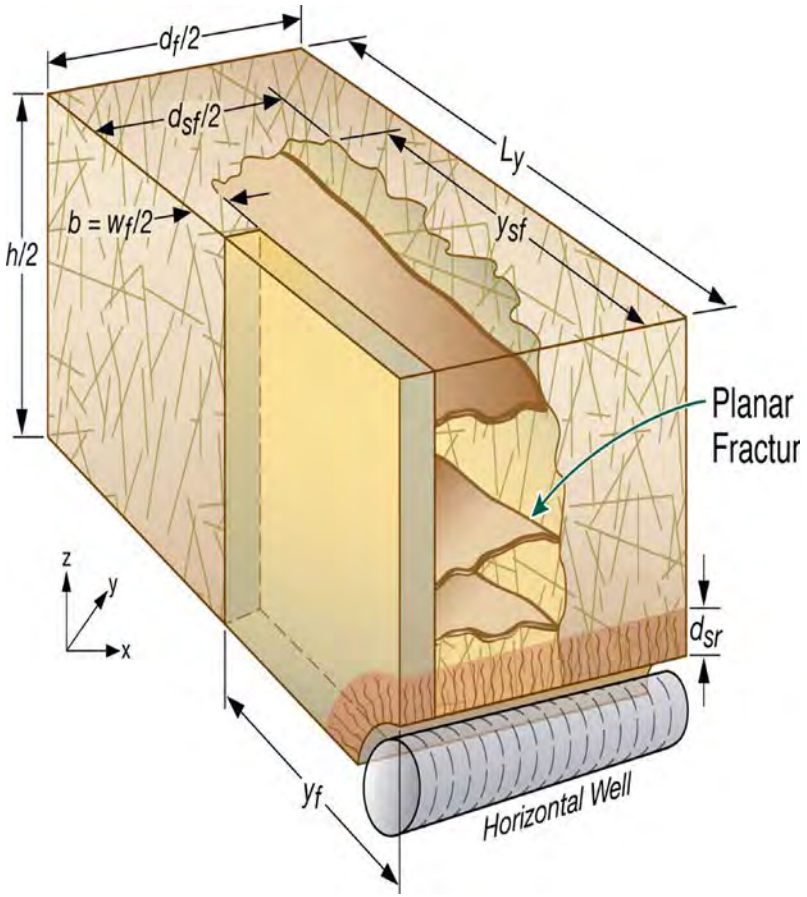


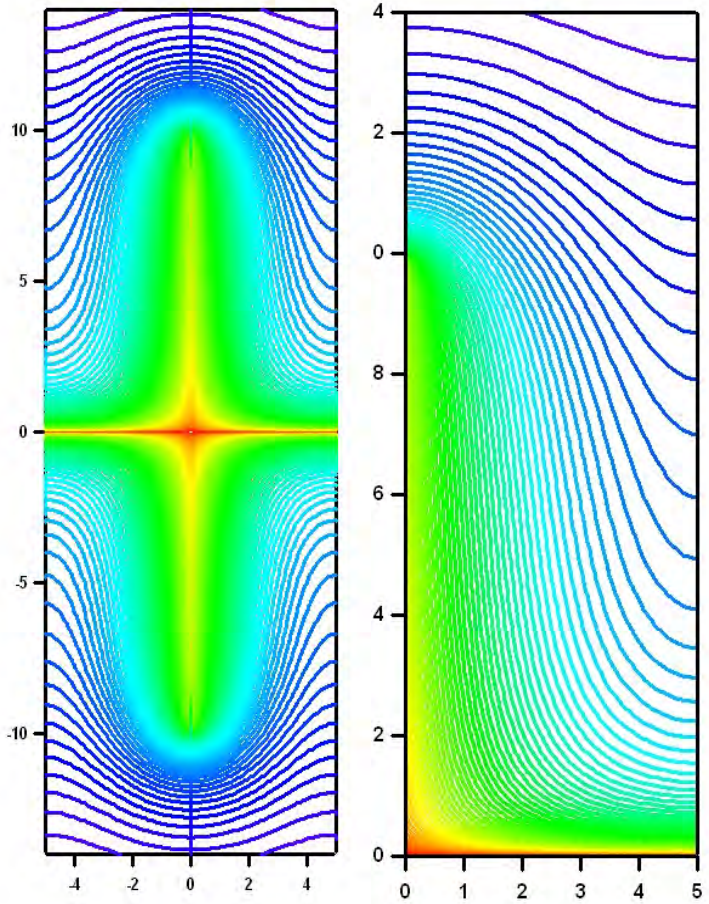


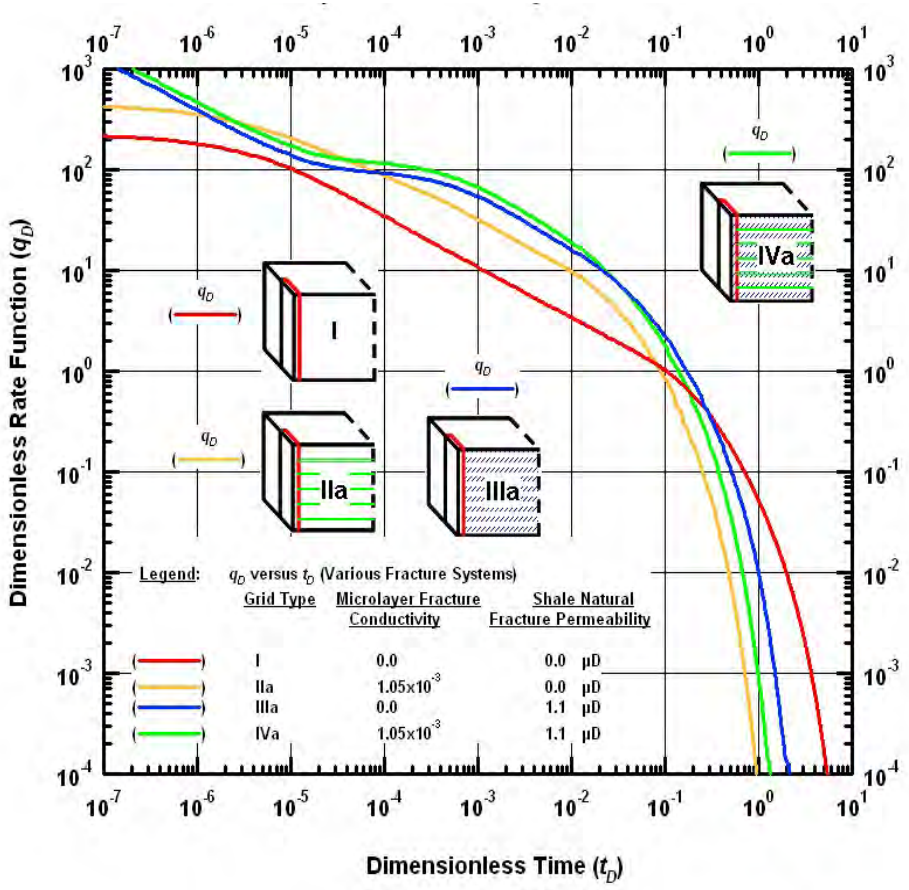


Changes in densities, fluid movements and imbibition

TAMU Research: Coupled Flow + Thermal+ Geomechanical + Geochemical Simulation







Complex Fracture System

Simulated Pressure Field

Predicted Production

Research Team:
Lawrence Berkeley National Laboratory

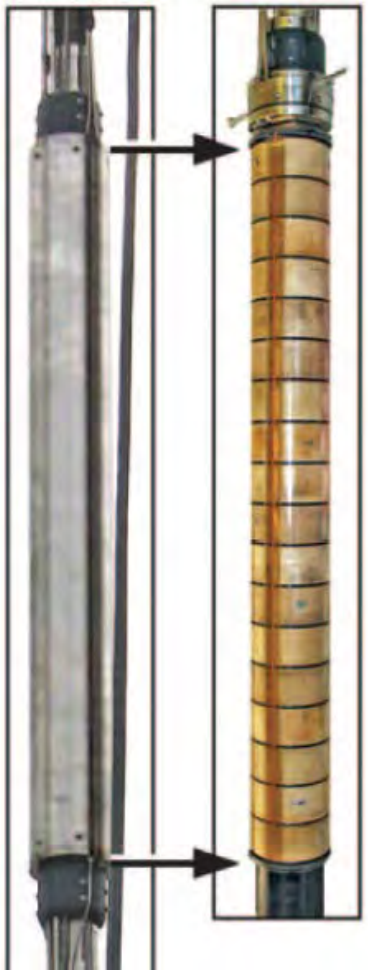
Key Research Personnel:

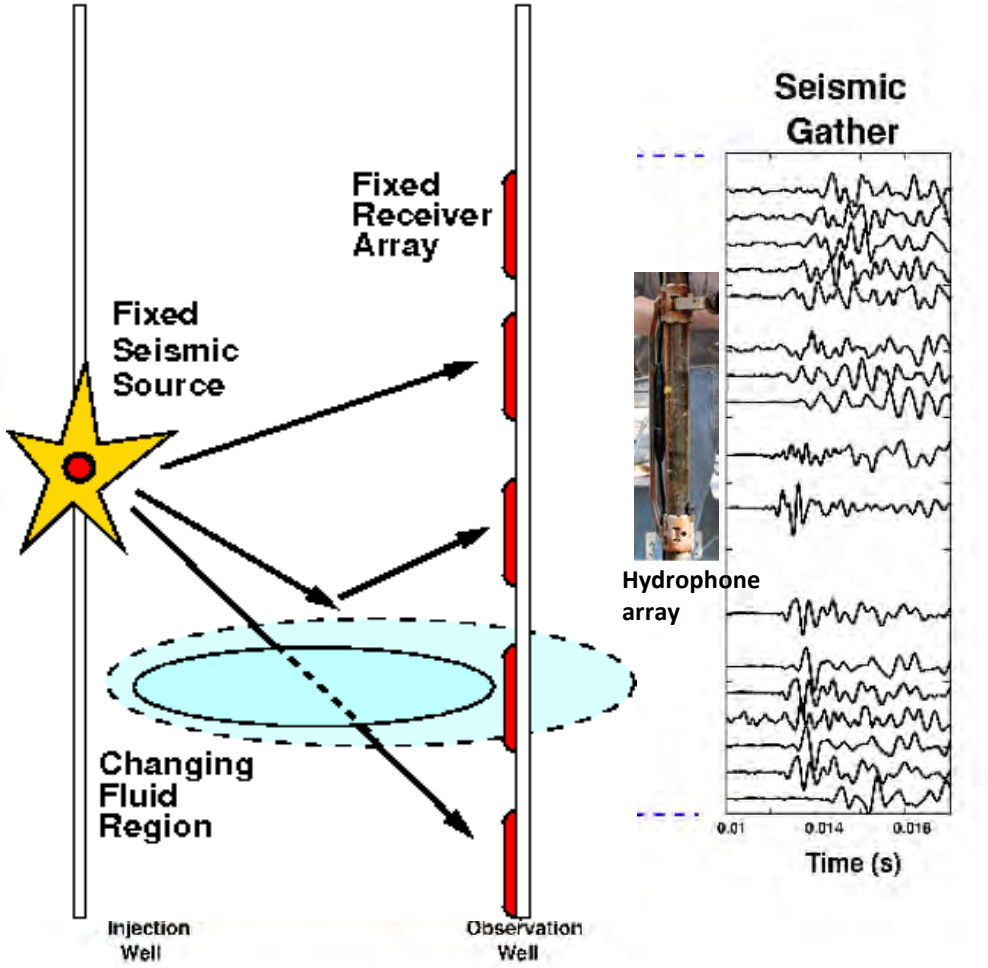
- Jens Birkholzer (Multiphase flow)
- Kurt Nihei (Seismic modeling & imaging)
- Jonathan Ajo-Franklin (Seismic monitoring: DAS/DTS/DSS)
- Barry Freifeld (Borehole instrumentation: DAS/DTS/DSS)
- Kenichi Soga (Geomechanics & DSS)

Subject Matter Experts:

- Jonny Rutqvist (geomechanics), Yingqi Zhang (flow optimization), Matt Reagan (multiphase flow modeling), Tim Kneafsey (lab hydromechanics), Seiji Nakagawa (rock physics & rock mechanics), Abdullah Cihan (microscale modeling), Yves Guglielmi (geomechanics), Tom Daley (borehole geophysics & DAS), Ernie Majer (MEQ & borehole seismics), Quanlin Zhou (EOR)

LBNL: Continuous Active Source Seismic Monitoring (CASSM)





- Temporal Resolution (< 5 min)
- Precise repeatability (~10 ns)
- Stacking -> Excellent S/N
- Real-time Acquisition
- Borehole & surface sources.
- Deployment to 10,500 ft & 120 C
- Largest deployment 12 S x 72 R
- Real-time seismic tomography

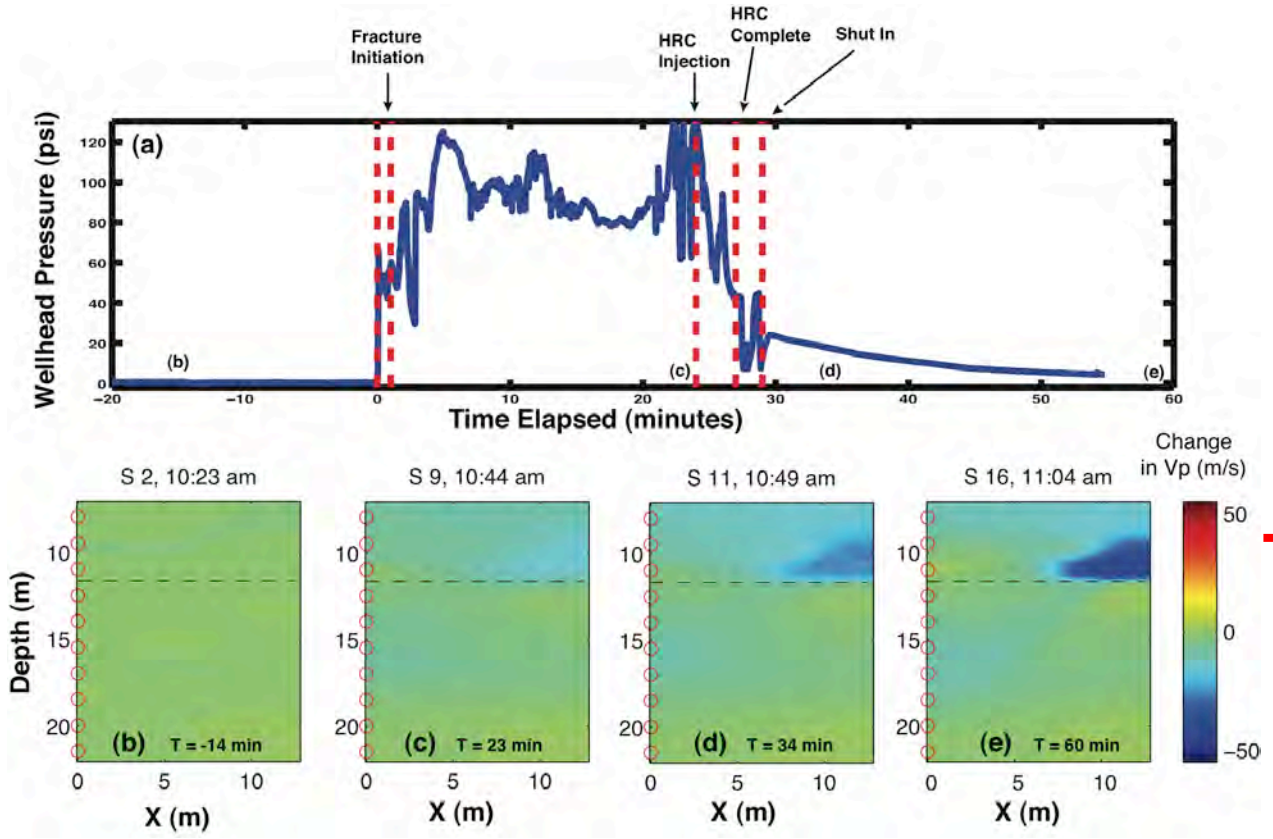
LBNL: CASSM Application for Fracture Mapping

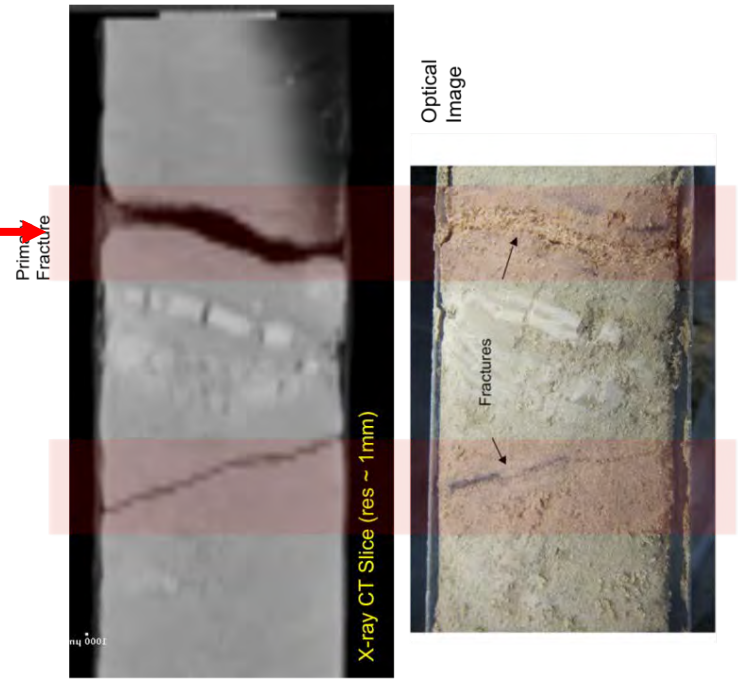
Near-surface hydraulic fracturing test at Warren AFB, Cheyenne, WY (DOD)

Analysis: Traveltime tomography, confirmatory boring

Result: Successful image of fracture (low Vp zone), confirmed by coring

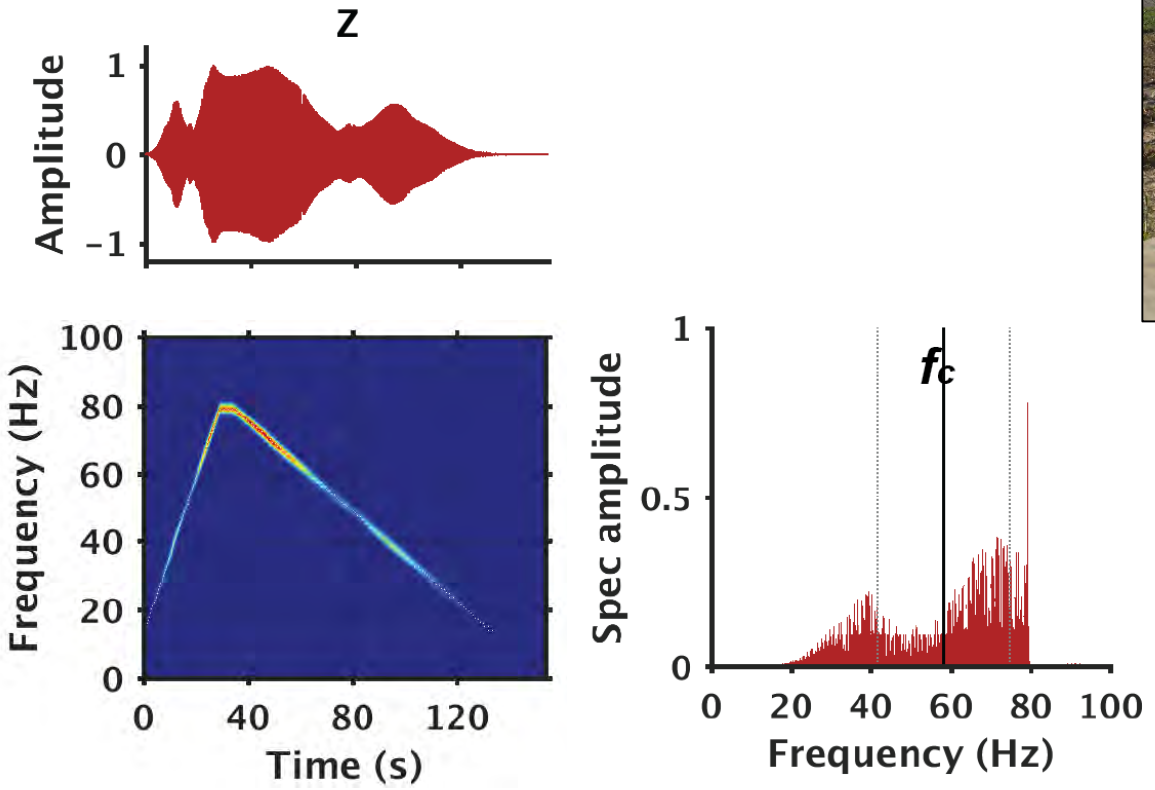
Implication: CASSM provides one of the few approaches for real-time fracture imaging





LBNL: Surface Orbital Vibrator for permanent monitoring

Sweep-based:
controlled release of seismic energy



Research Team:
Stanford University

Key Research Personnel:

- Mark Zoback (Reservoir geomechanics)
- Fatemeh Rassouli (Laboratory testing)
- Robert Cieplicki (Machine learning)
- Lei Jin (Poroelastic modeling)

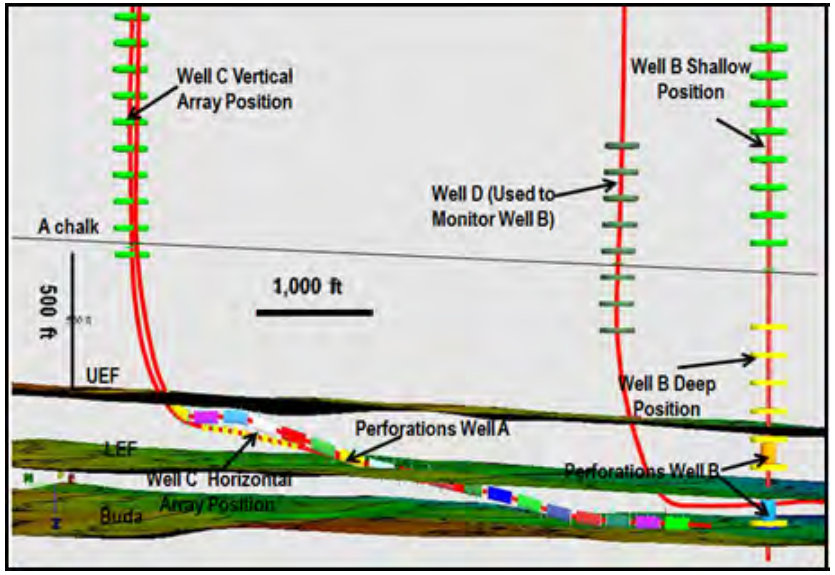
Optimization of Geosteering

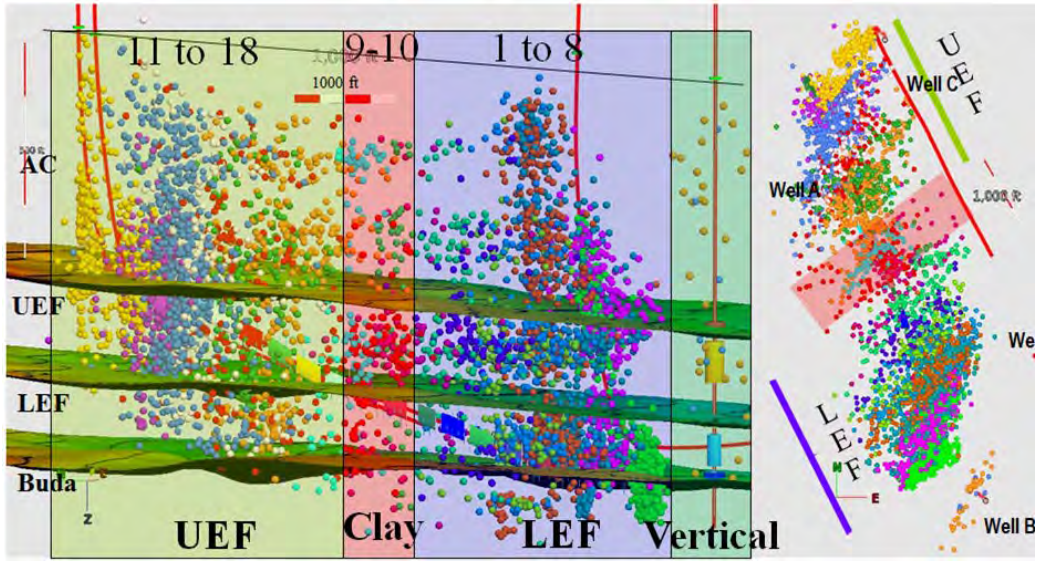
- Laboratory measurement of elastic and viscoplastic properties using core samples
- Analysis of drilling/logging data
- Optimal targeting of Eagle Ford sub-intervals for landing laterals

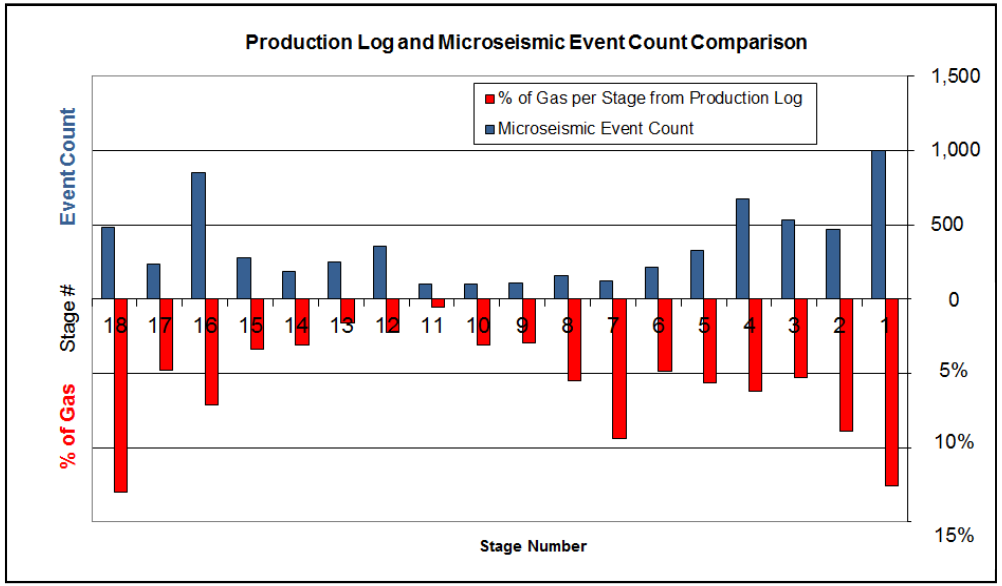
Geomechanical Modeling

STANFORD
UNIVERSITY

Landing Point Optimization - Eagle Ford







Patel et al., URTeC, 2013

Expected Deliverables

- First direct measurement of fracture geometries before and after re-fracturing
- Best to date measurements of created complex fracture geometries
- Well production profiles and bottomhole pressures in producing and observation wells throughout the life of the project
- Best data set to date for calibration of fractured well performance models, reservoir simulators

Expected Deliverables

- Best to date measurement of created fracture height in Eagle Ford
- First shared information of field-monitored EOR pilot in the Eagle Ford
- 4D seismic monitoring of fractured reservoir volume
- Laboratory data supporting field experimentation

Current Status

- Project start date of April 1, 2018
- Test site selection has been finalized
- Research team is designing observation wells and monitoring program based on anticipated re-frac well completion
- Established JIP for additional support from operating and service companies (five members currently)

Sponsor Companies (JIP)

- A Joint Industry Project (JIP) has been established in support of the EFSL study
- Sponsors to provide in-kind services and/or cash contribution
- JIP currently includes two large operators and three large service companies
- A Technical Advisory Committee (TAC) will be established with representation from all JIP sponsors
- Additional sponsor companies are welcome

Next Steps

- Securing surface access rights for monitoring equipment
- Scheduling drilling rig / frac crew for Phase 1 of the study.
- Drilling and instrumentation of the two observation wells expected in January 2019
- Analyzing monitoring data and history match modeling to begin late February 2019

Questions and Comments?