Role of Shale Geomechanical Changes Affecting Gas and Fluid Flow

Dustin Crandall, NETL

October 16th, 2020

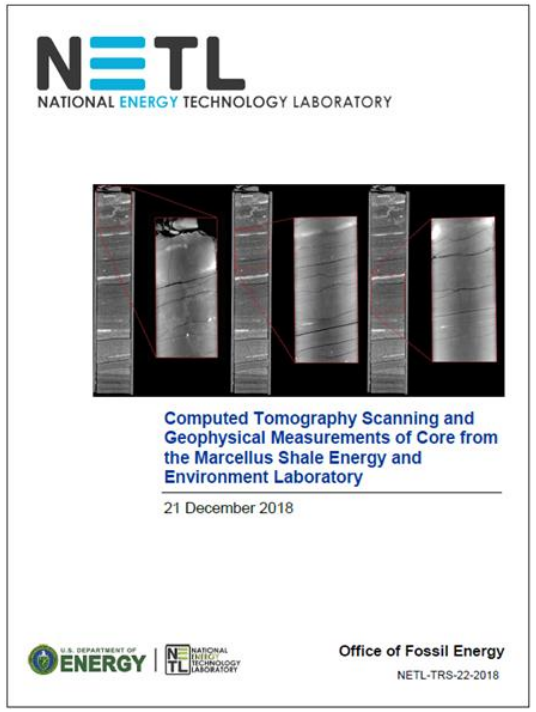
Team

First and foremost, **thank you** to the team of researchers who are performing this work.

- Ale Hakala is the portfolio technical lead and Sandy Borek is the project manager.
- Magdalena Gill, Bryan Tennant and Johnathan Moore lead the in-situ fracturing shearing work.
- Thomas Paronish and Rhiannon Schmitt lead the core characterization work, with help from Johnathan and Scott.
- Johnathan Moore and Scott Workman lead the oil Huff and Puff work.
- Terry McKisic and Johnathan Moore ensure that the lab is functional, data can be transferred/processed, and have kept us sane during COVID.

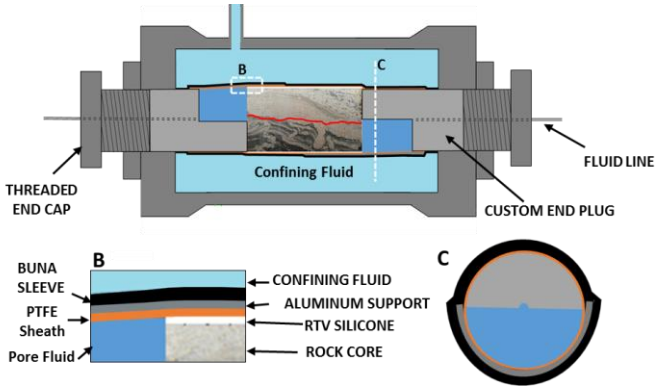
Role of Shale Geomechanical Changes in Affecting Gas and Fluid Flow

2017 – 2018*	2019	2020	2021	Total Project (2017 – 2021)

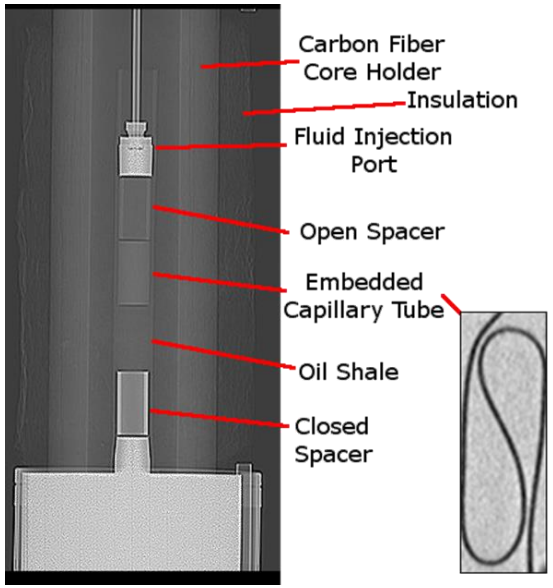


Non-destructive core characterization for baseline reservoir information

Apparatus to Measure Fracture Aperture Changes under Confining Stress



Apparatus to Measure Live Hydrocarbon Huff n' Puff



One-of-a-kind laboratory techniques developed to study mechanics and flow changes under reservoir pressure and temperature conditions.

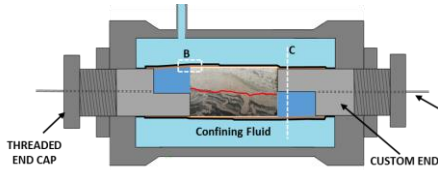
End Product:
Improved ability to characterize reservoir geomechanics and new relationships for model-based predictions of hydrocarbon flow.

Bottom Line Up Front

What's the benefit of this fundamental research to an applied lab?

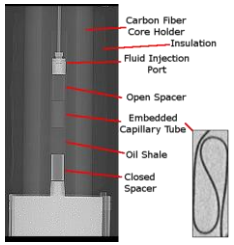
Barriers to increasing recovery that the project is addressing.

- Understanding how rocks from different basins behave, under representative subsurface conditions, is important to improve recovery.
- Enabling wide distribution of characterizations and results to partners and public.



The barriers are being addressed with,

- Unique experimental equipment to examine real rocks, under real conditions.



The extent the barriers have been/are being addressed by the project

- Fundamental understanding of behavior increased through publications.
- Continued collaborations with industrial, academic, and national laboratory partners to ensure our fundamental measurements and understandings resonate.

Project Objectives & 2020 Milestones

NATIONAL ENERGY TECHNOLOGY LABORATORY

Task 2 to end March 2021

2.1 Fracture Shearing

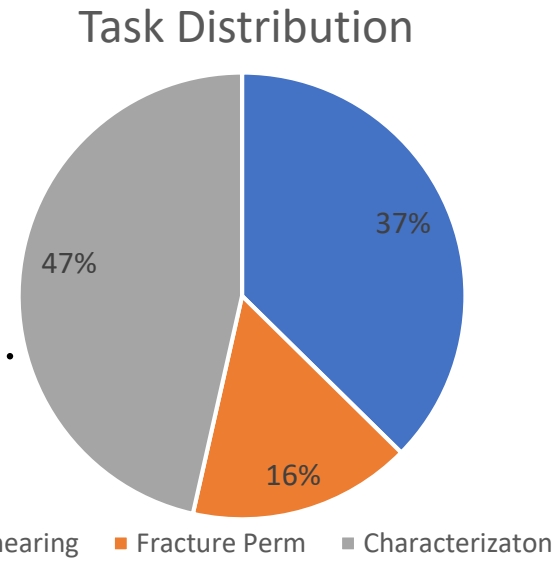
- Impact to flow of geomechanical alteration in fractures from different formations. Universal and unique behaviors.
  - Complete shearing experiments from additional two formations.

2.2 Fracture Adjacent Permeability Measurements

- New effort, born from need expressed by modelers. What is the matrix permeability perpendicular to a fracture, and how does this change with alteration?
  - Go/No-Go Dec 2020, proof of concept functioning.

2.3 Fundamentals of Shale/Core Characterization

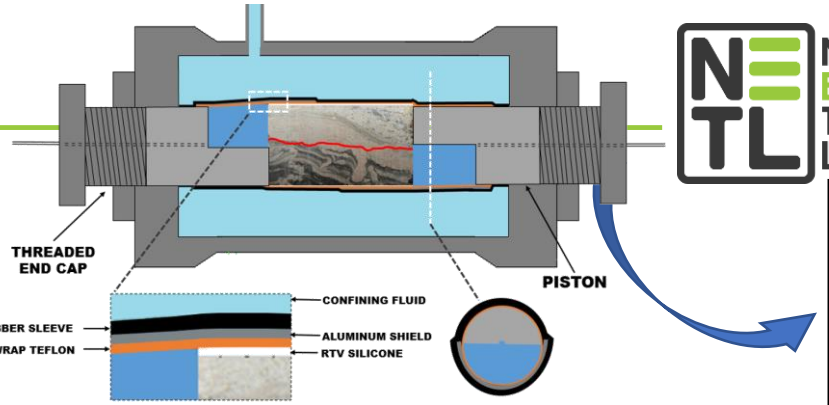
- HFTS huff and puff assessment with Wolfcamp cores and live oil.
  - Report to HFTS working group (delayed).
- Characterization of cores for HFTS lab group and of field laboratories.
  - At least 3 core characterizations published.

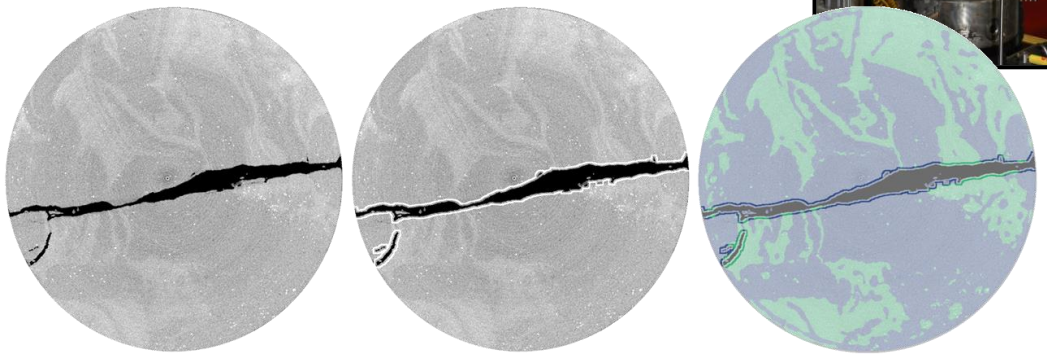


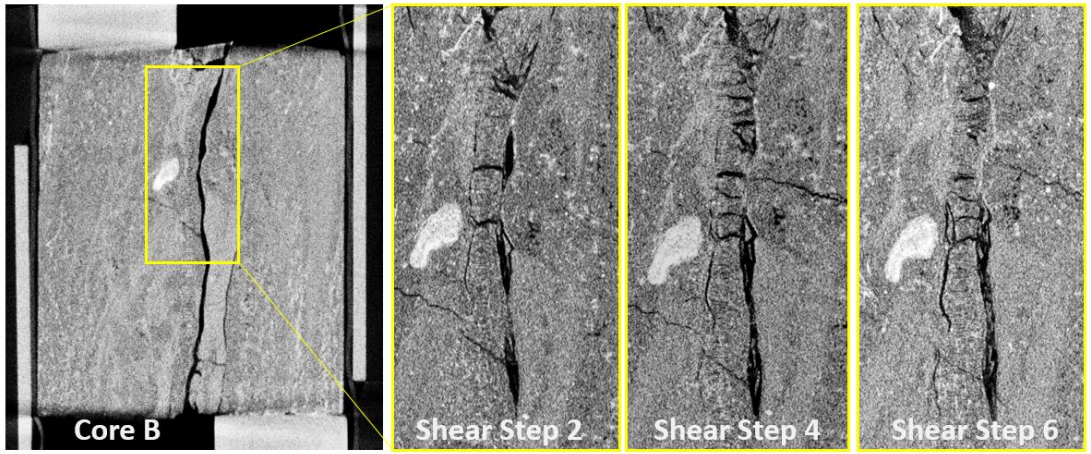
Fracture Shearing

Marcellus, Utica, and Eau Claire Shales examined

- Controlled shear of fractured shale, under elevated pressure, with flow and full 3D scans
- 3 separate Utica shearing completed
  - Analysis is still underway
  - Very tight fractures with low permeability
- Paper describing impact of core heterogeneities submitted to Int J of Rock Mech and Mining Sciences
  - Developed new image processing techniques to discern fracture adjacent materials
  - Influence of local gouge creation on full fracture permeability evaluated



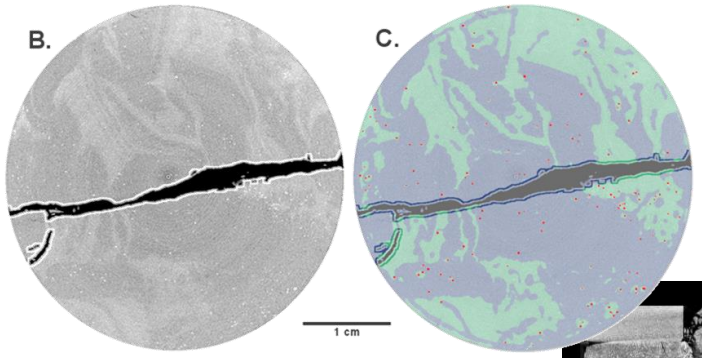


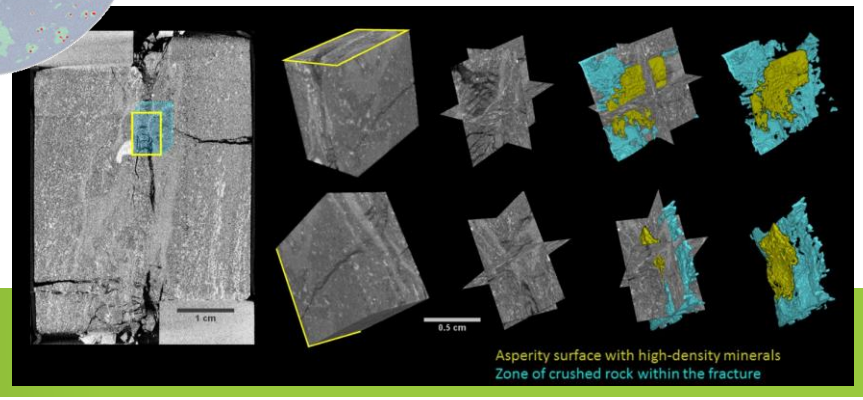


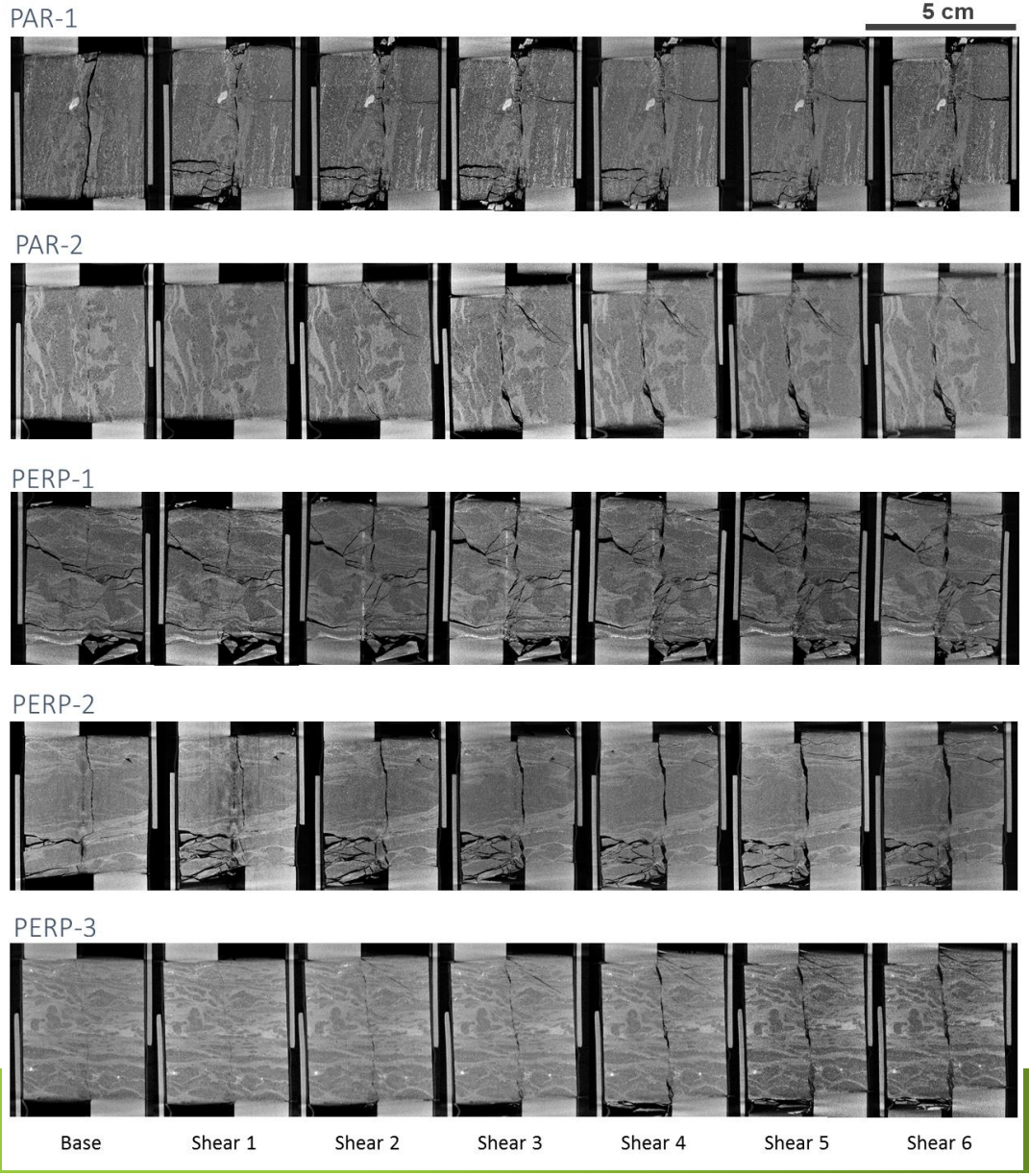
Take Aways from Recent Shearing Submission

Multiple heterogeneous shale cores examined

- Fracture orientation to bedding matters
- The material adjacent to the fracture plane has a significant bearing on the fracture development during shear
- Small zones of gauge development can significantly reduce fracture transmissivity



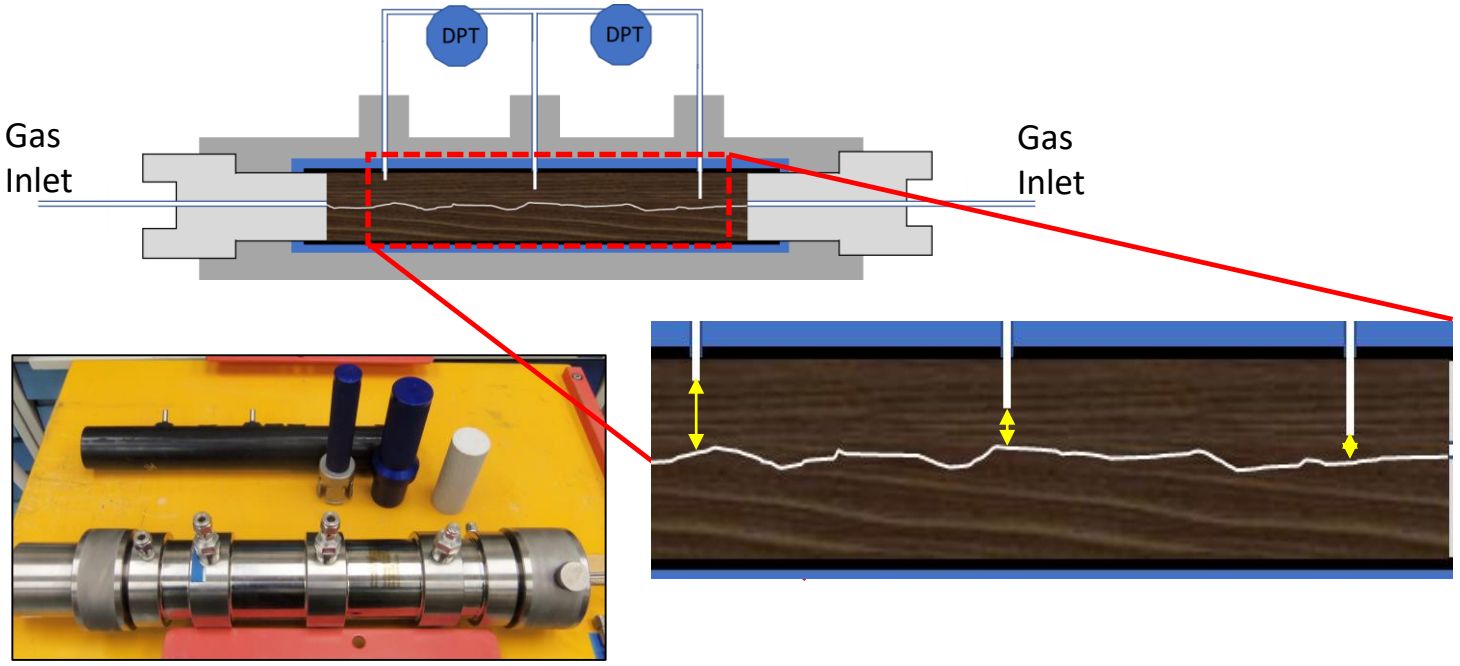




Matrix Permeability Adjacent to Fracture

Need became apparent from discussions with model developers

- As work in Task 3 shows, geochemical alteration in fractured shale can be significant
  - We can measure changes in the fracture permeability
- But what does this dissolution or precipitation mean for flow in the matrix perpendicular to the fracture?
- Is this critical for stopping or enhancing flow to the fractures?

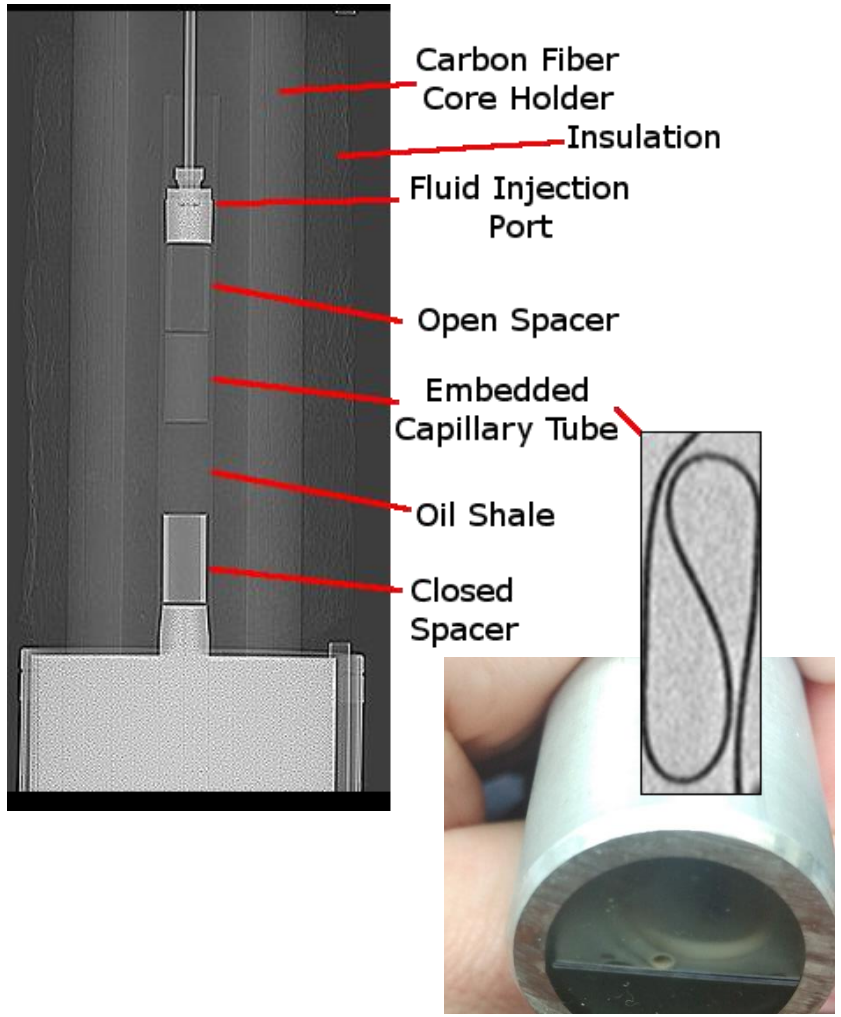


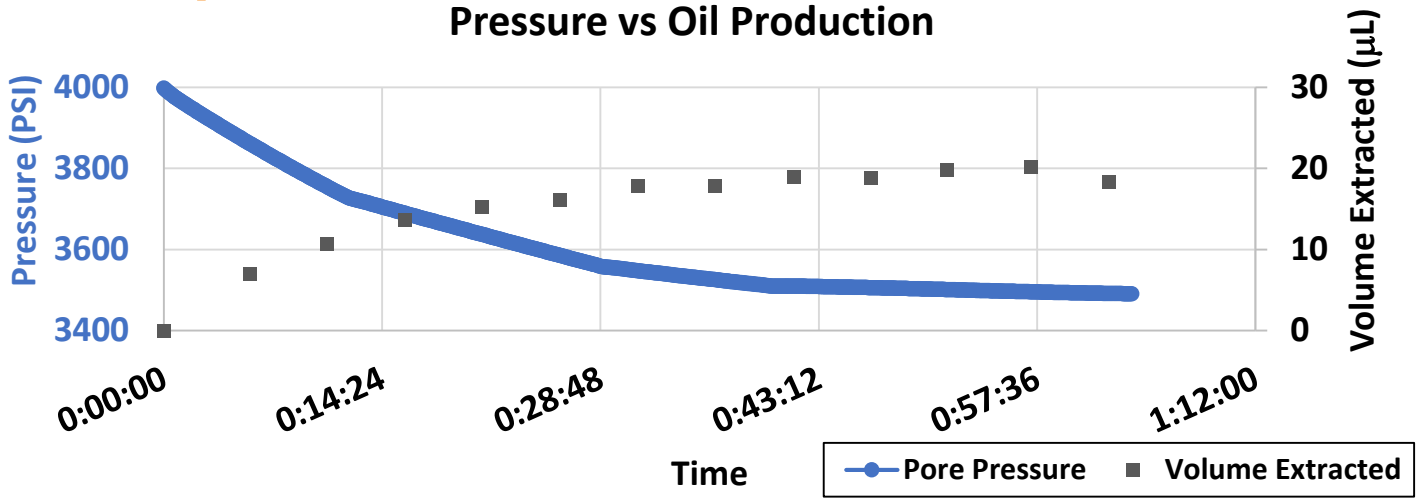
Concept

- Holes drilled perpendicular to the fracture, to different depths.
- Pore pressure applied to fracture, while system under pressure.
- Different lengths between holes and fracture will enable measurements of bulk permeability, potentially revealing information about the depth of alteration in the matrix.

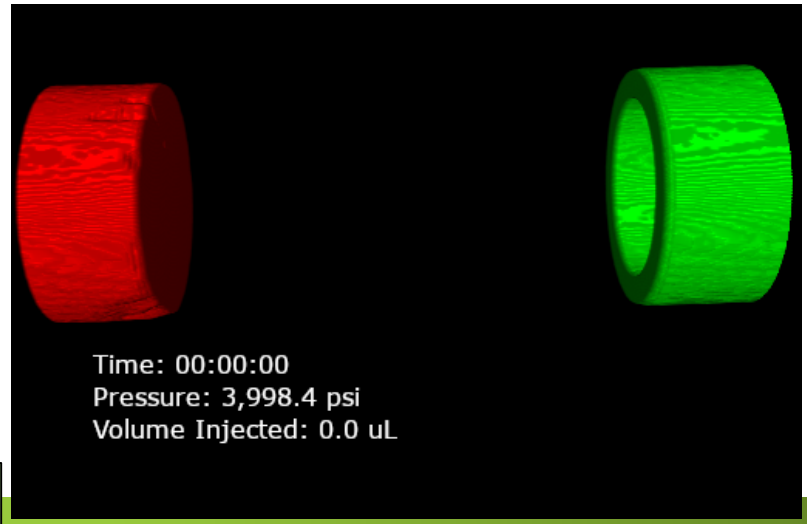
HFTS Huff and Puff

Live oil measurements without depressurization





- Live oil testing on Permian shale sample
- While maintaining T&P, reduce injection pressure and measure volume of oil produced



2020 URTeC: A New Methodology to Evaluate Huff and Puff Effectiveness at in-Situ Conditions
Johnathan Moore, Dustin Crandall and Scott Workman

Core Characterization Workflow

Not "one size fits all", but what we strive for at a minimum

NATIONAL ENERGY TECHNOLOGY LABORATORY

SESAR SYSTEM FOR EARTH SAMPLE REGISTRATION

EDX Energy Data eXchange — NETL's Energy Data eXchange

https://edx.netl.doe.gov/group/core-characterization

Joining our repository

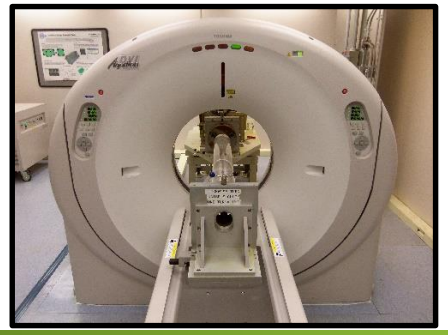
New cores arrives

On loan

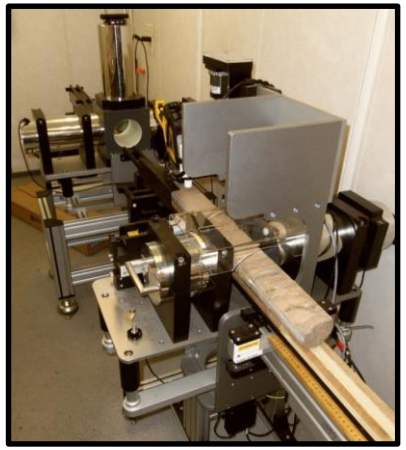
Entered into System for Earth Sample Registration (SESAR)

IGSN: XXXXXXXXX
Name: My Sample Name
Type: My Sample Type
Depth Min: My Sample Other Names

Scanned in Medical CT

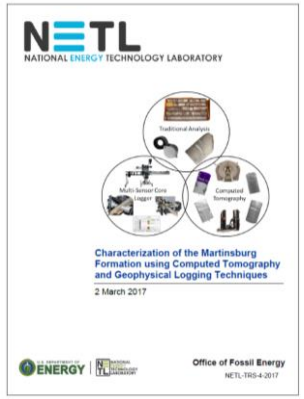


Scanned in Multi-Sensor Core Logger (MSCL)

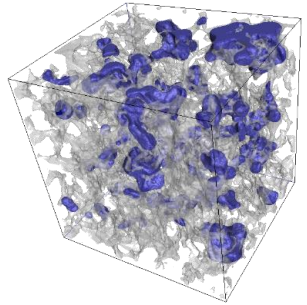


Upload → Energy Data eXchange (EDX) online

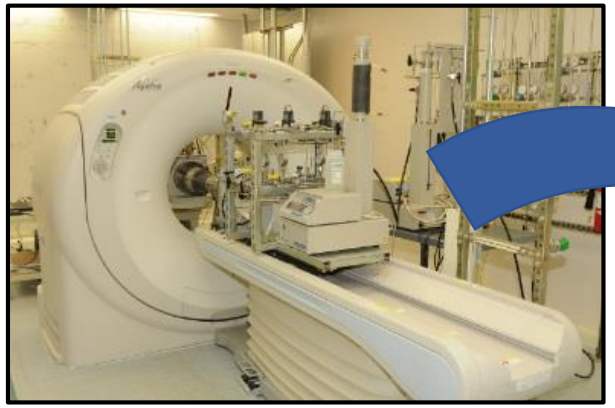
Publish → NETL's Technical Report Series

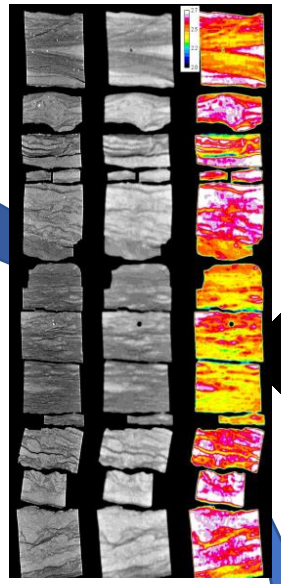


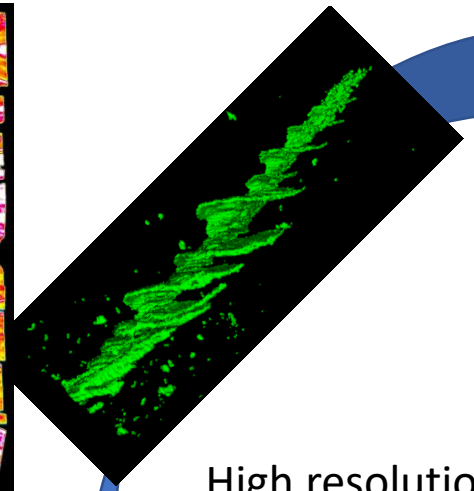
Upload → Digital Rocks Portal

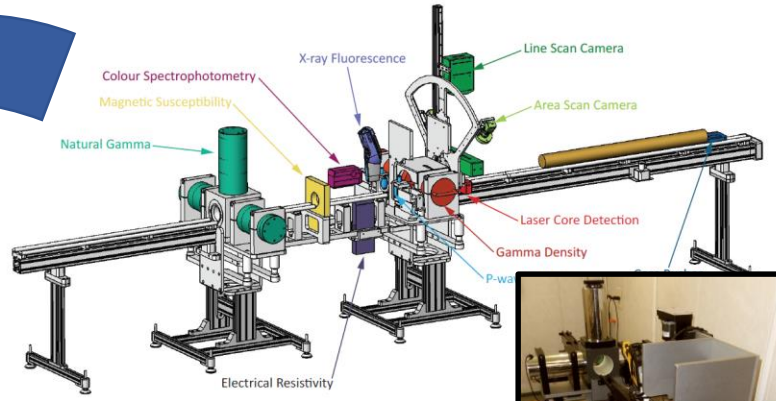


Core Characterization Data Collection



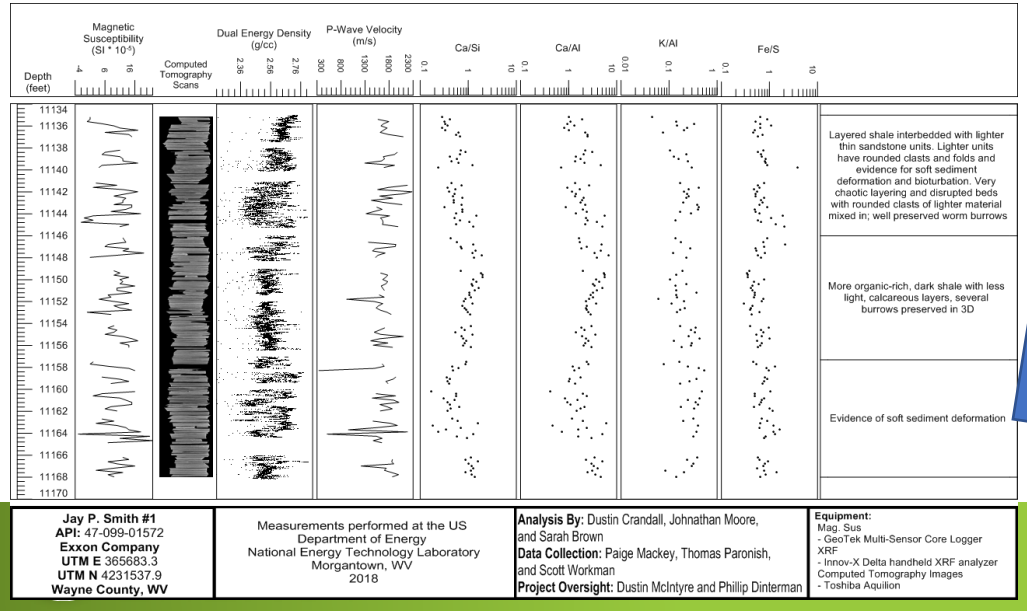


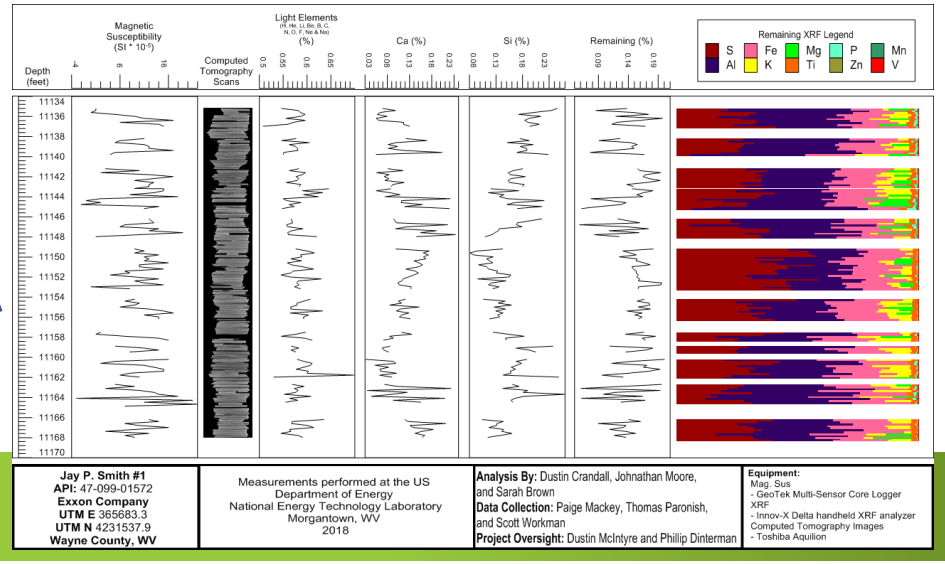




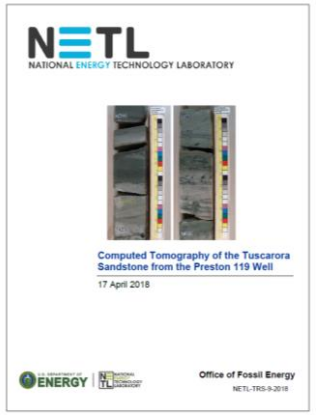
Dual energy scanning for structural features and internal density

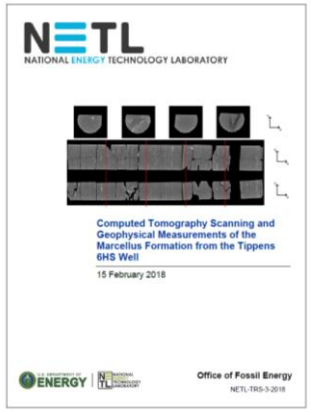
High resolution core logging for XRF, p-wave, magnetic susceptibility, and gamma density



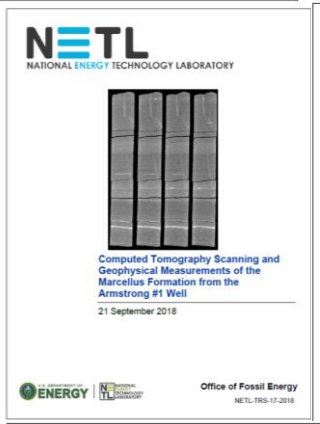


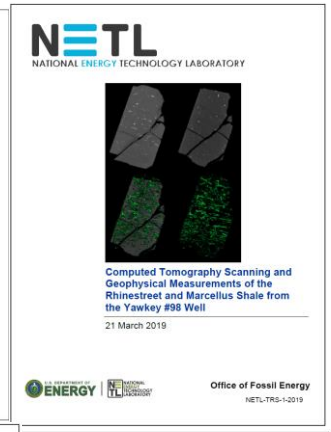
Core Characterization Published Reports

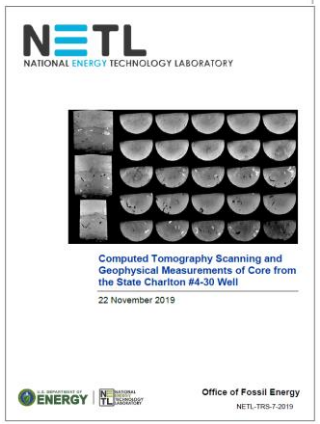


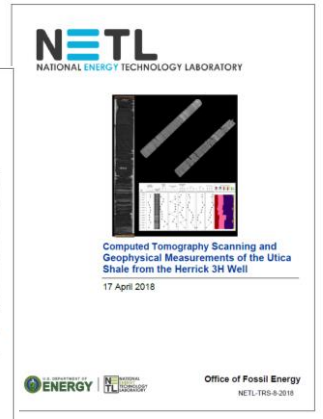


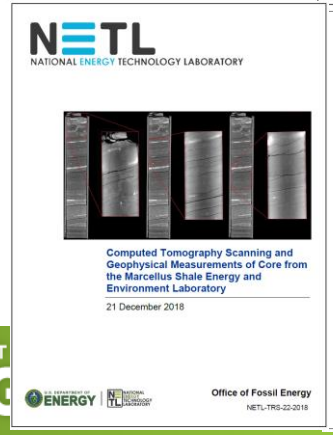
- Full reports and data sets available on https://edx.netl.doe.gov/group/core-characterization

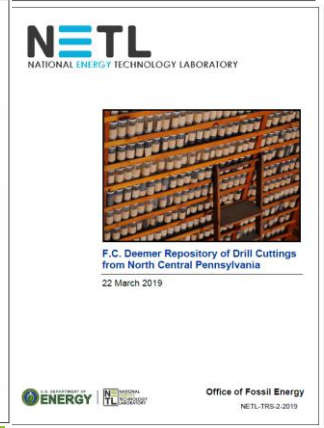


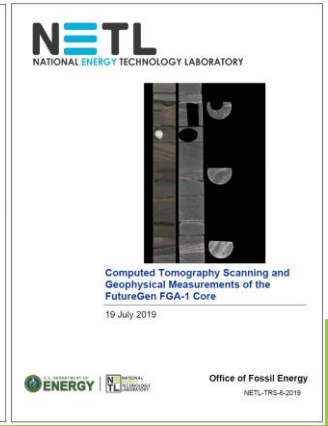


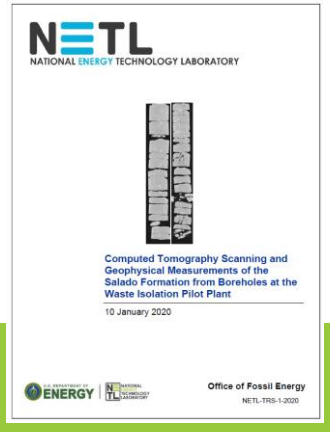


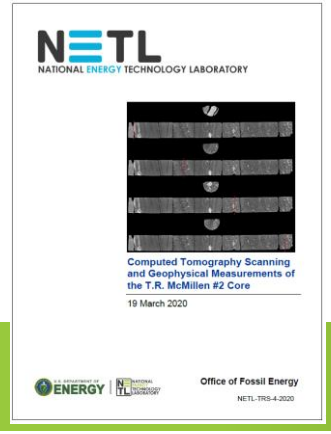


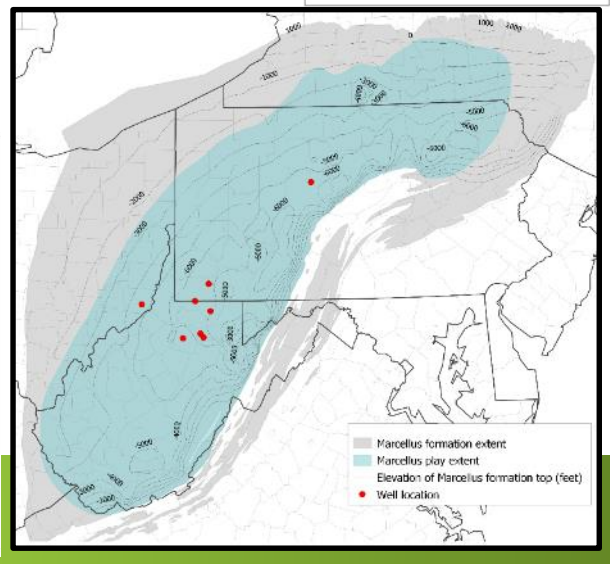












Core Characterization

This year

- HFTS Laboratory group
  - Scanning for SLAC and others (Task 19)
- MSEEL Phase 2 scanned
  - Waiting for core to return for final measurements
- Caney Shale Field Lab
  - Oklahoma State University/Joe Renk
  - Core scanned at NETL
- ESUP Field Lab (Lower Huron Shale)
  - Virginia Tech/Rob Vagnetti
  - 100 subcores to scanned NETL
- CO_2/EOR in Trenton/Black River
  - Battelle/Gary Covatch
  - Representative core from MSGS scanned

- Tom Paronish invited to OSU in February to present on NETL capabilities

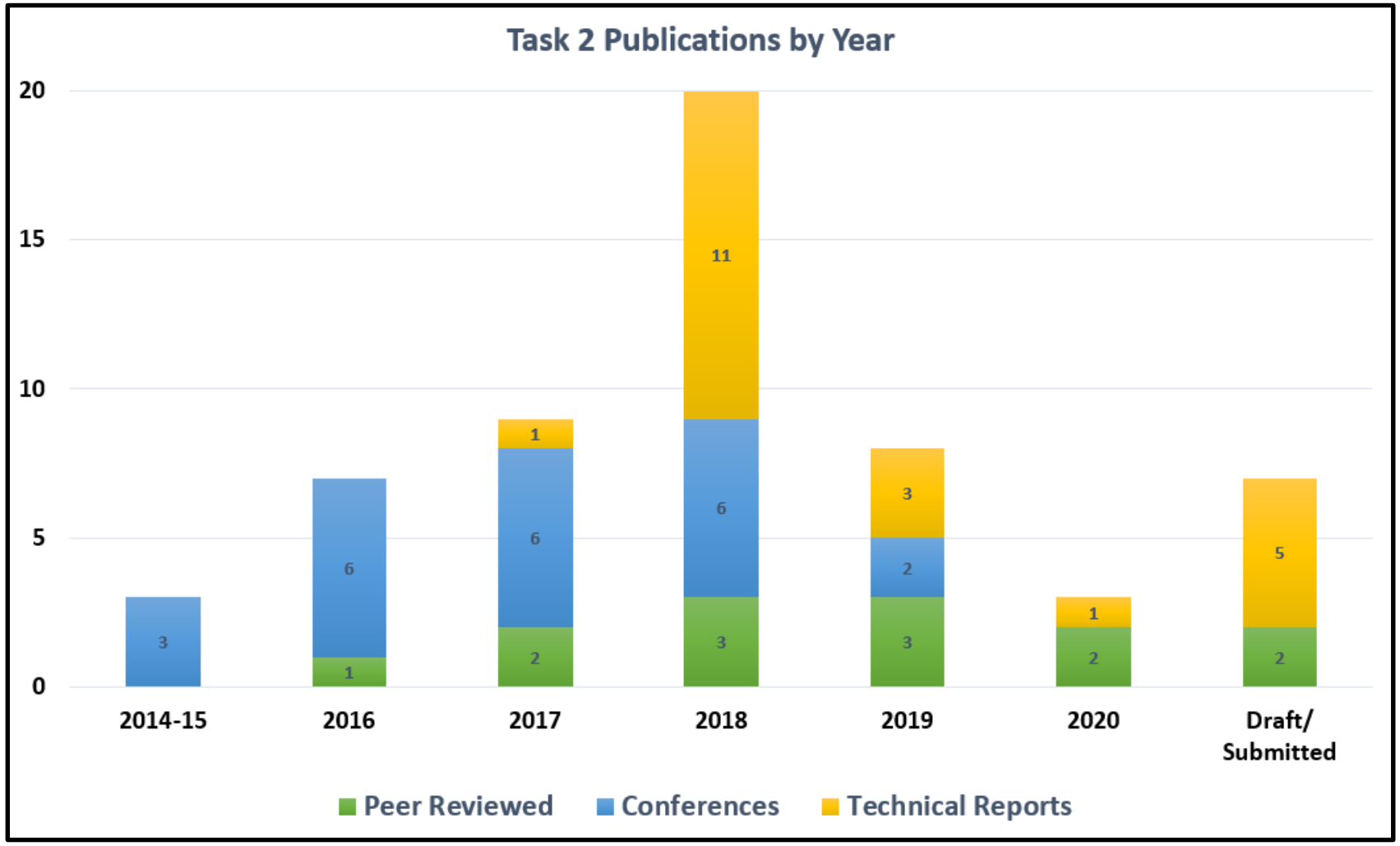
650 feet of Caney Shale
At NETL, 5/19/2020

2020 URTeC: Multi-Scale facies and Chemostratigraphic Analysis of Two Middle Devonian Marcellus Shale wells in Northern West Virginia, USA
Tom Paronish, Randy Toth, Tim Carr, Dustin Crandall, and John Moore

Publications and Products

50 publications (and 7 drafts or submissions)

- Early conference publications, as research matured to peer reviewed manuscripts.
- WVU/MSEEL collaboration in 2017-2018 kicked of the core characterization work (TRS jump).
- Avg Imp Factor: 2.73



Summary

Even with COVID, laboratory work is going well

- On track to complete milestones this year
  - Will be delayed in reporting Huff n Puff results to HFTS, but happy with new method
- Couple of URTeC conference papers this year
  - Others cancelled (e.g. GSA regional) but we'll keep looking for opportunities
- Continued /increased interest in characterization from field laboratories
  - Three oil/gas focused technical reports this year will not be an issue
- Hopeful for the matrix permeability method adjacent to fractures method
  - To early to claim success, but I think we'll be good with this
- Fracture shearing publications rolling out
  - NETL focused micro-heterogeneity impacts paper to IJRMMS
  - Comprehensive evaluation of different formations to be drafted late 2020