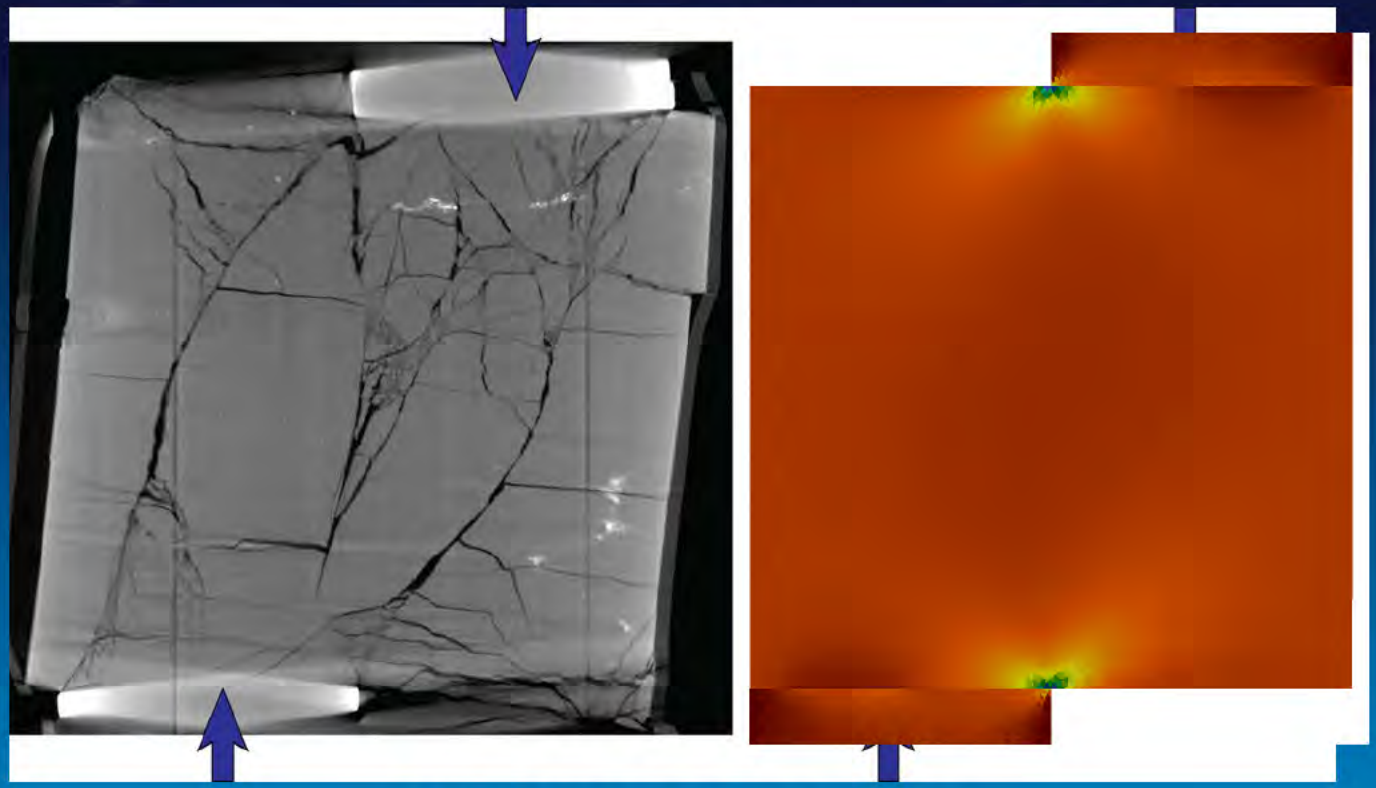
Fracture Permeability and Evolution of Marcellus Shale

Los Alamos NATIONAL LABORATORY EST.1943



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Motivation: What are fractures properties in the subsurface?

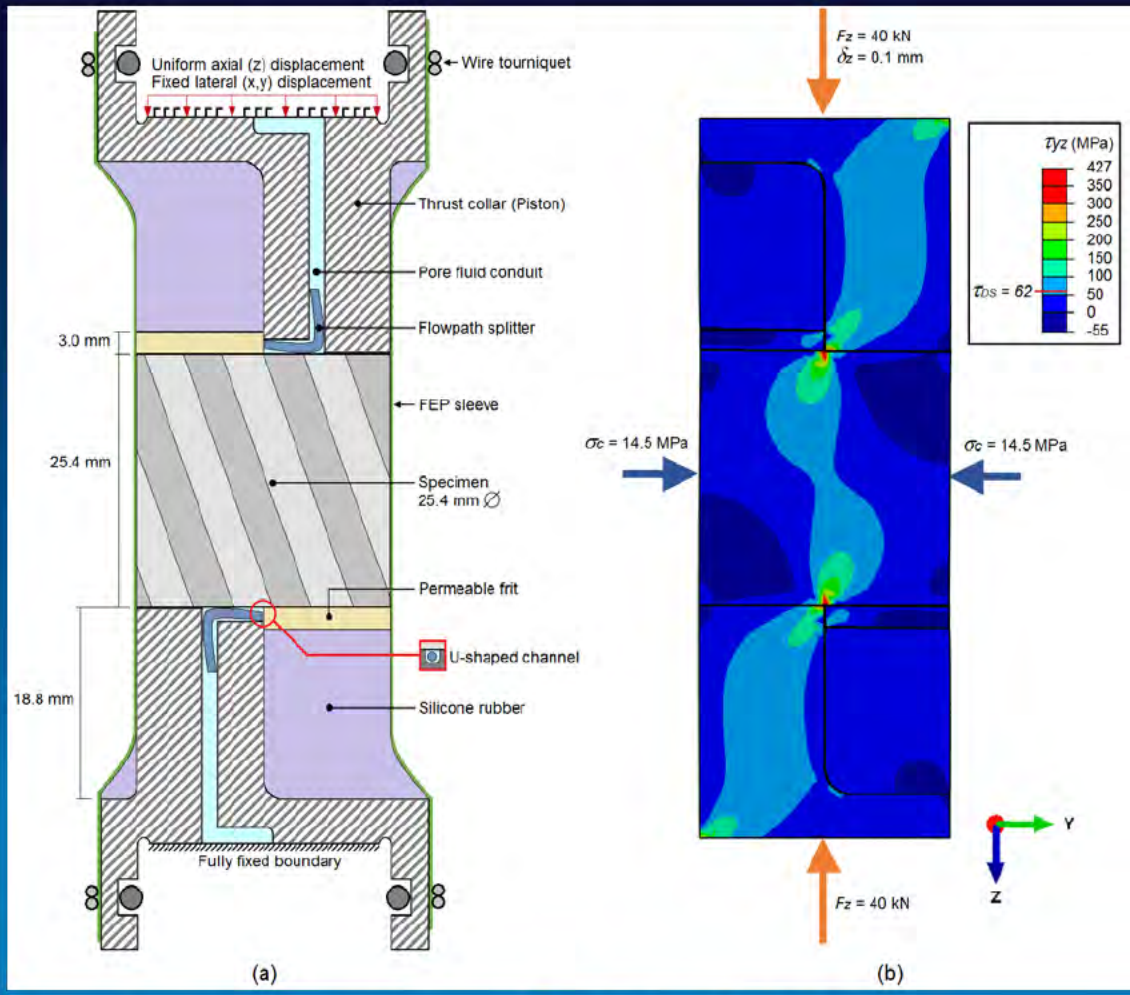
- The permeability of "freshly" formed and *in situ*—reactivated fracture systems is relatively unexplored
  - What is the effect of stress and fracture reactivation on the *in situ* permeability of fractured shale?
- Use integrated x-ray tomography and triaxial direct-shear coreflood methods to Marcellus shale at reservoir conditions
- Fracture permeability is key factor in
  - CO_2 sequestration, induced seismicity, hydraulic fracturing, geothermal energy, and nuclear waste disposal

Key Take-Aways

- A critical stress exists that separates highly permeable fractures from relatively impermeable fractures
- The effect of changes in effective stress (following fracture formation) are less significant than stress at formation
- A second critical stress exists determining whether fracture re-stimulation enhances permeability
- Under some conditions, permeability from fracture re-stimulation is relatively short-lived

Triaxial Coreflood & Tomography

- Max Pressure: 34.5 MPa (5,000 psi)
- Max Axial Load: 500 MPa (70,000 psi)
- Max Temperature: 100 °C



Carey et al., J. Unconv. O&G Res., 2015; Frash et al. (2016) JGR; Frash et al. (in revision) IJGGC

Low Confining Pressure: 3.5 MPa

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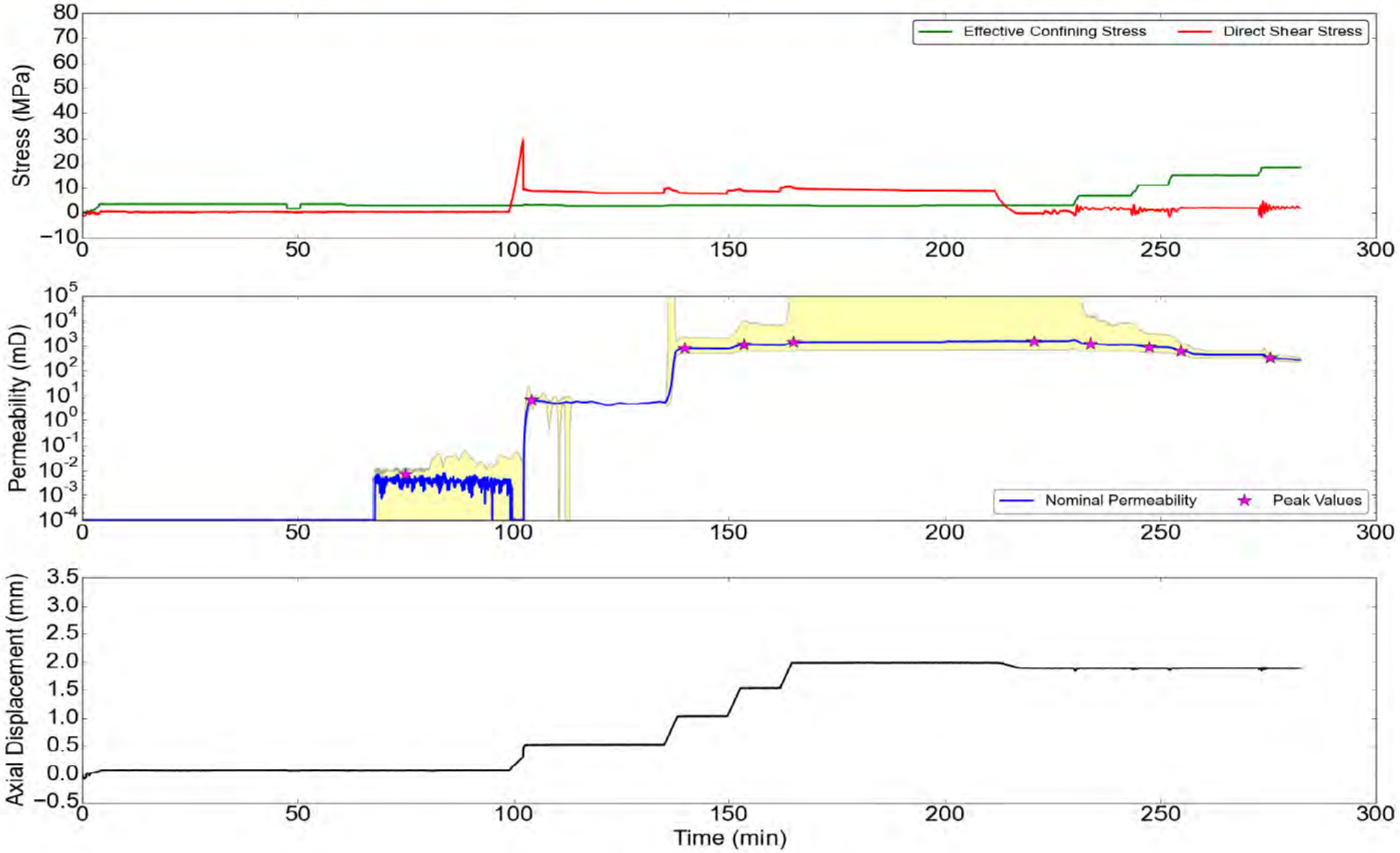

High Confining Pressure: 30 MPa

Marcellus: Q+F=20%, Carbonate=67%, Clay=13%

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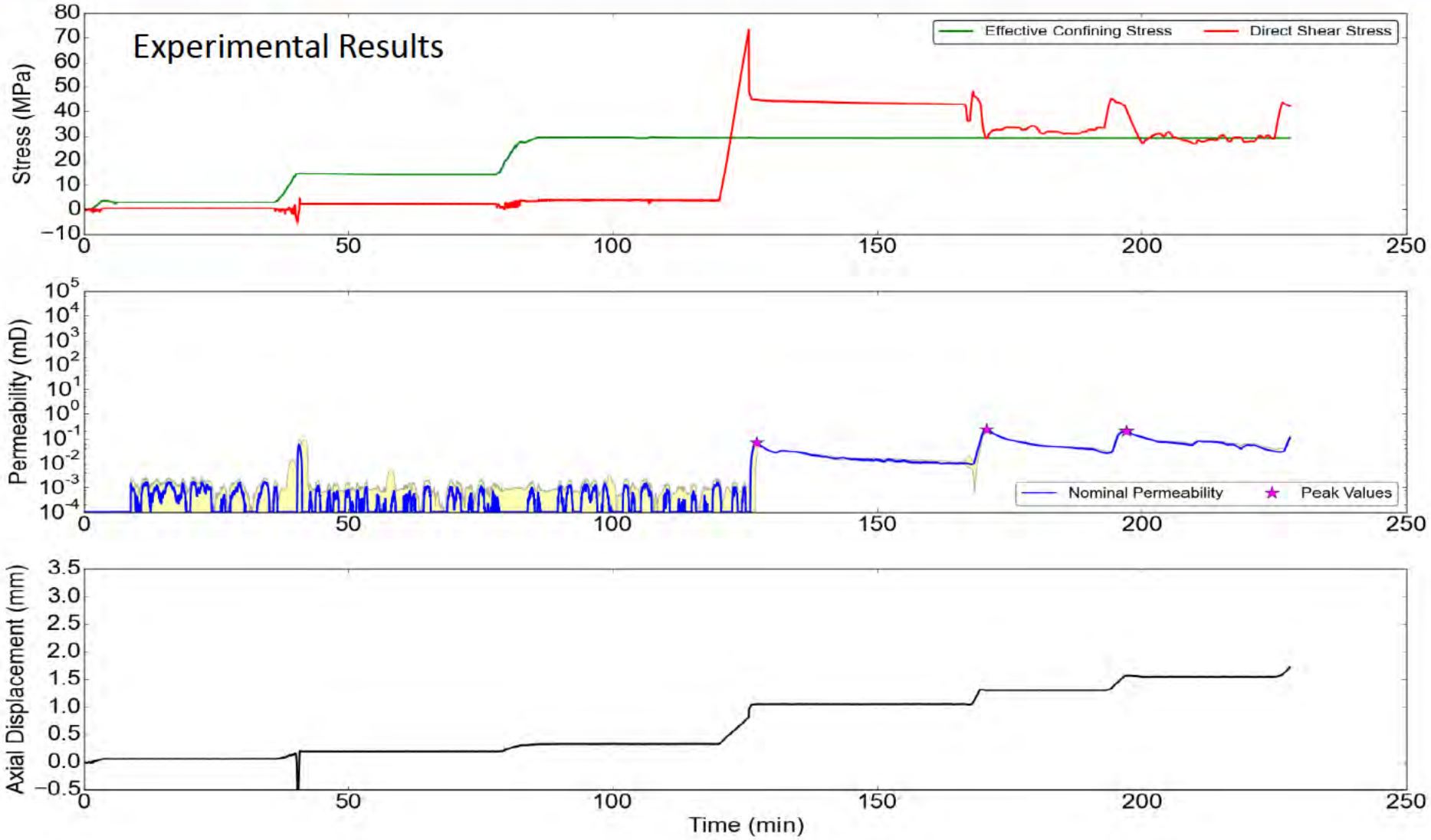

Low Confining Pressure: 3.5 MPa

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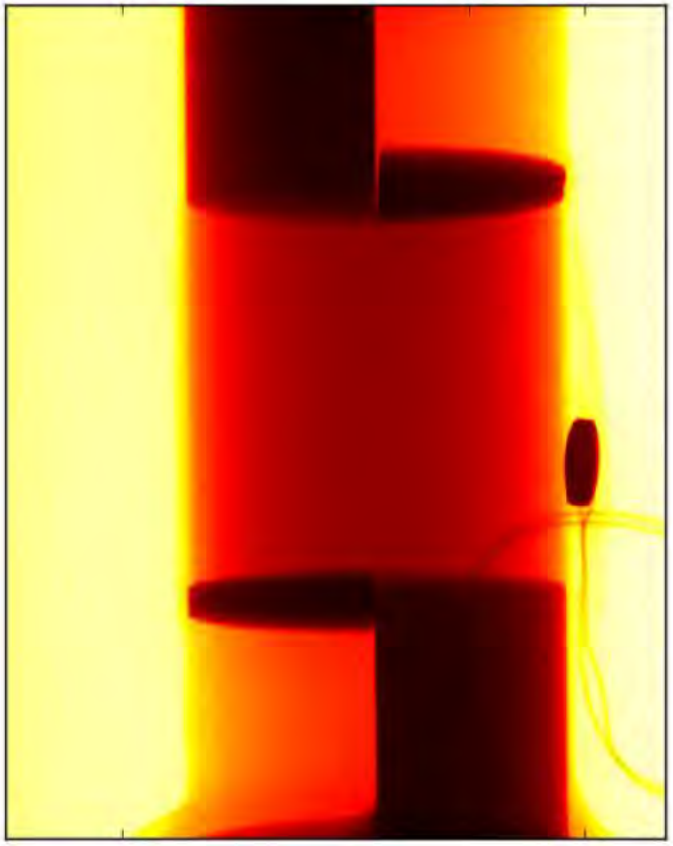
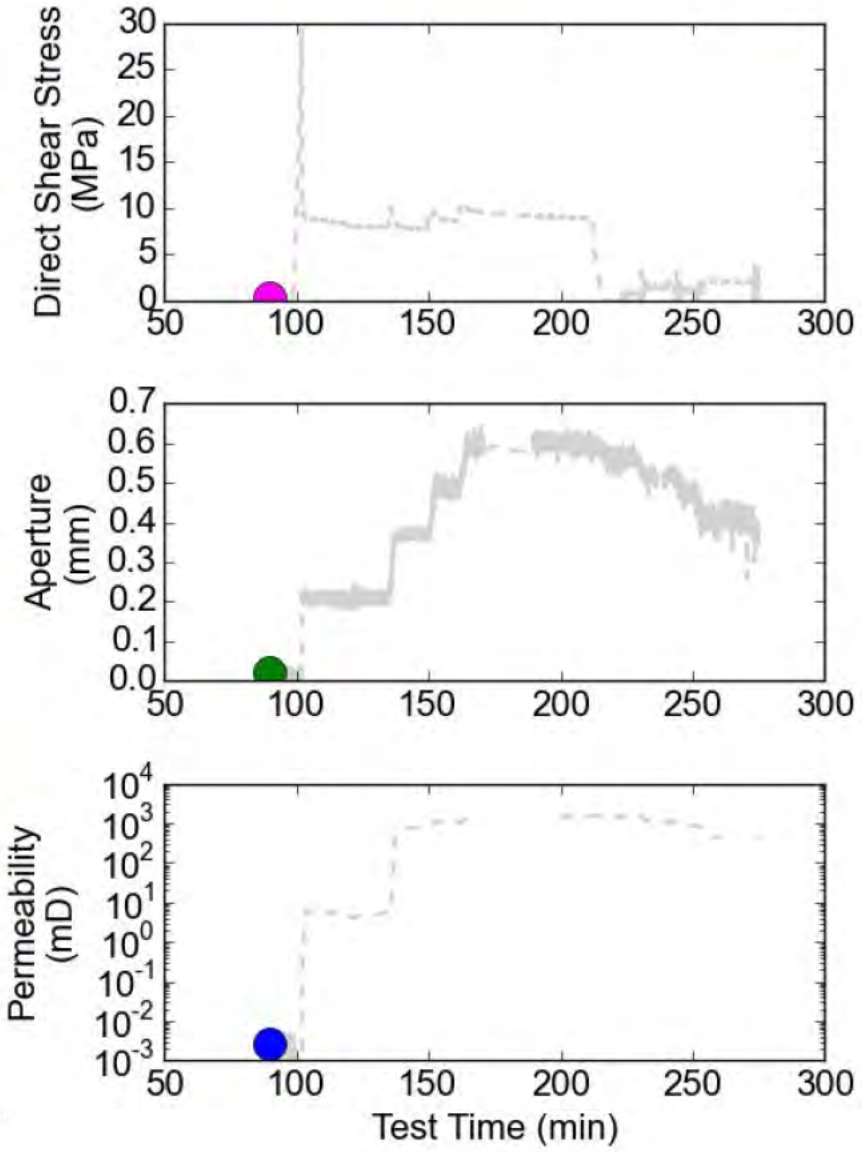
MS01-01:
3.0 MPa Effective Confining



90.00 min

False-Color X-ray Radiography



High Confining Pressure: 30 MPa

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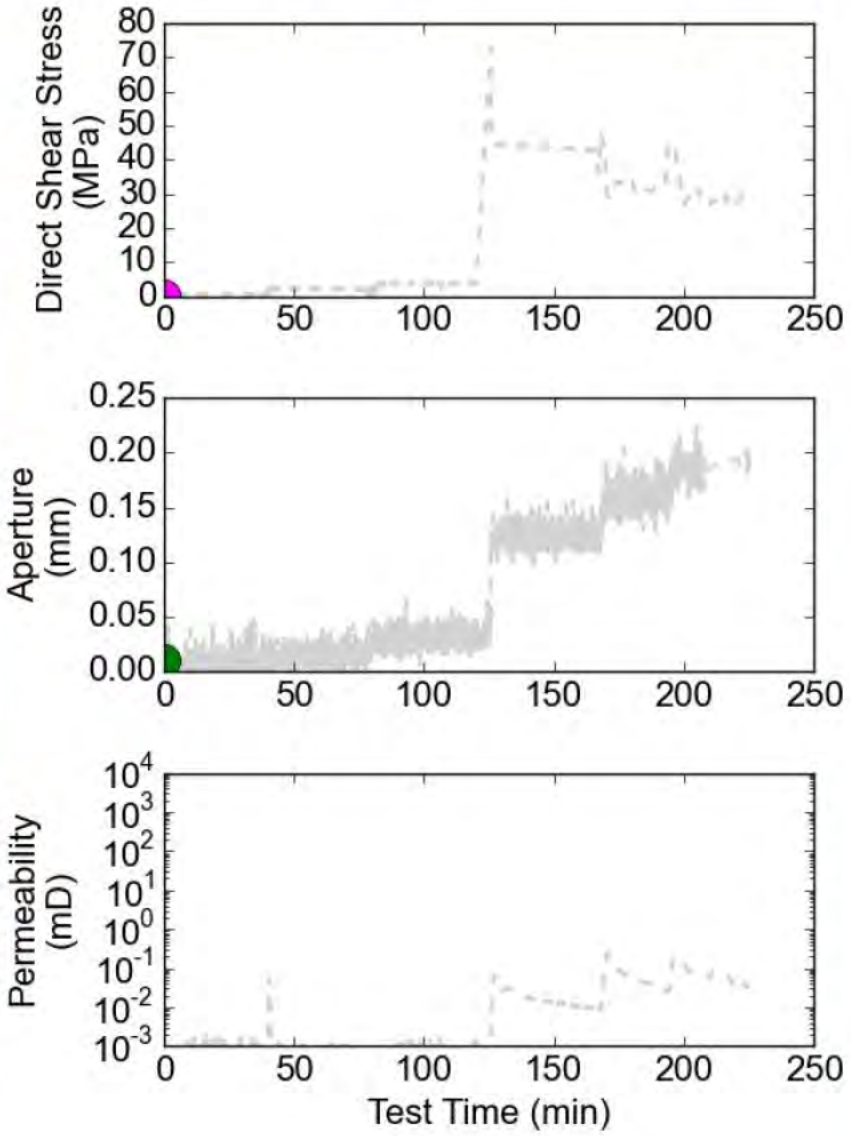
MS01-03:
0.0 MPa Effective Confining

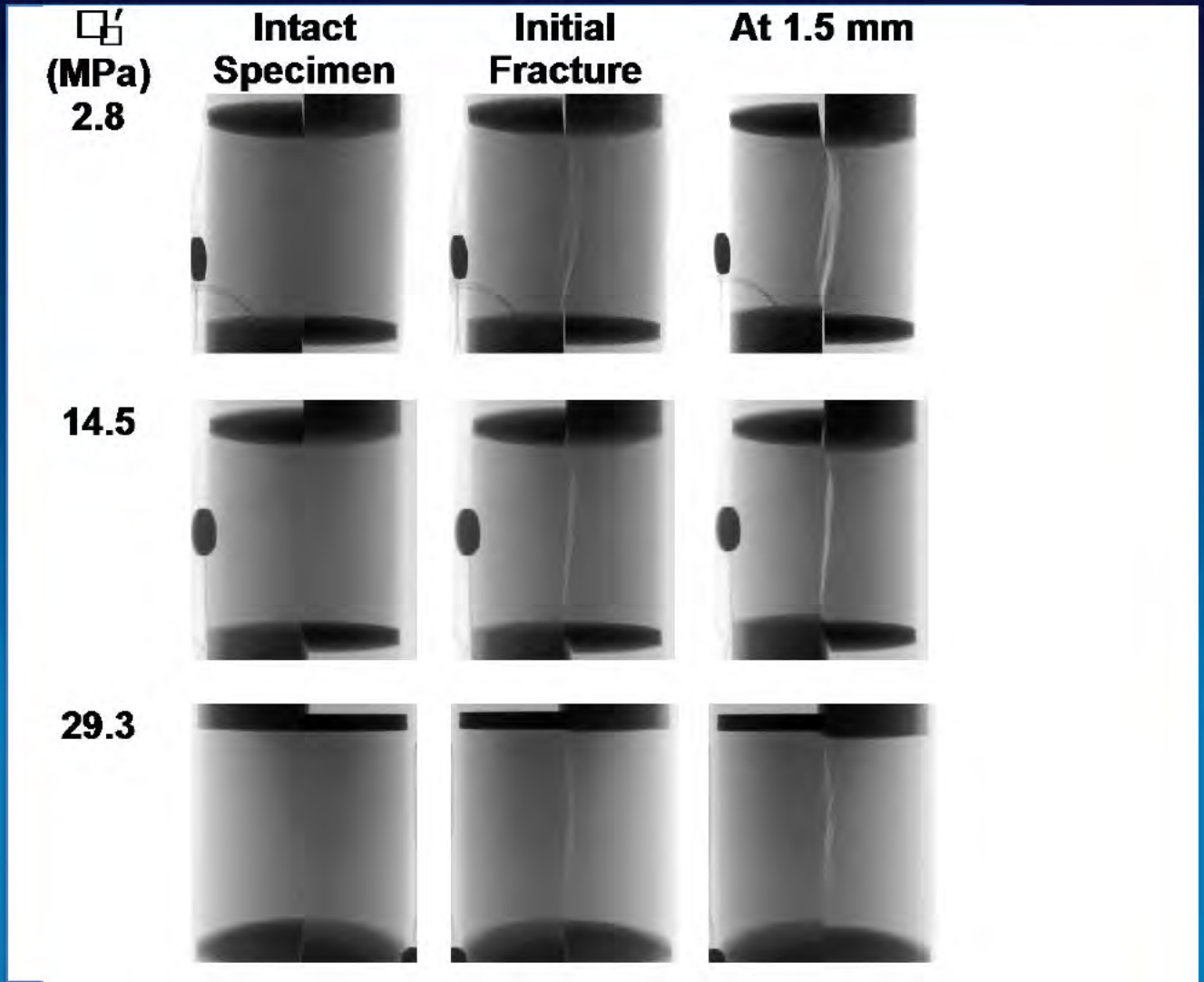
0.00 min

False-Color X-ray Radiography

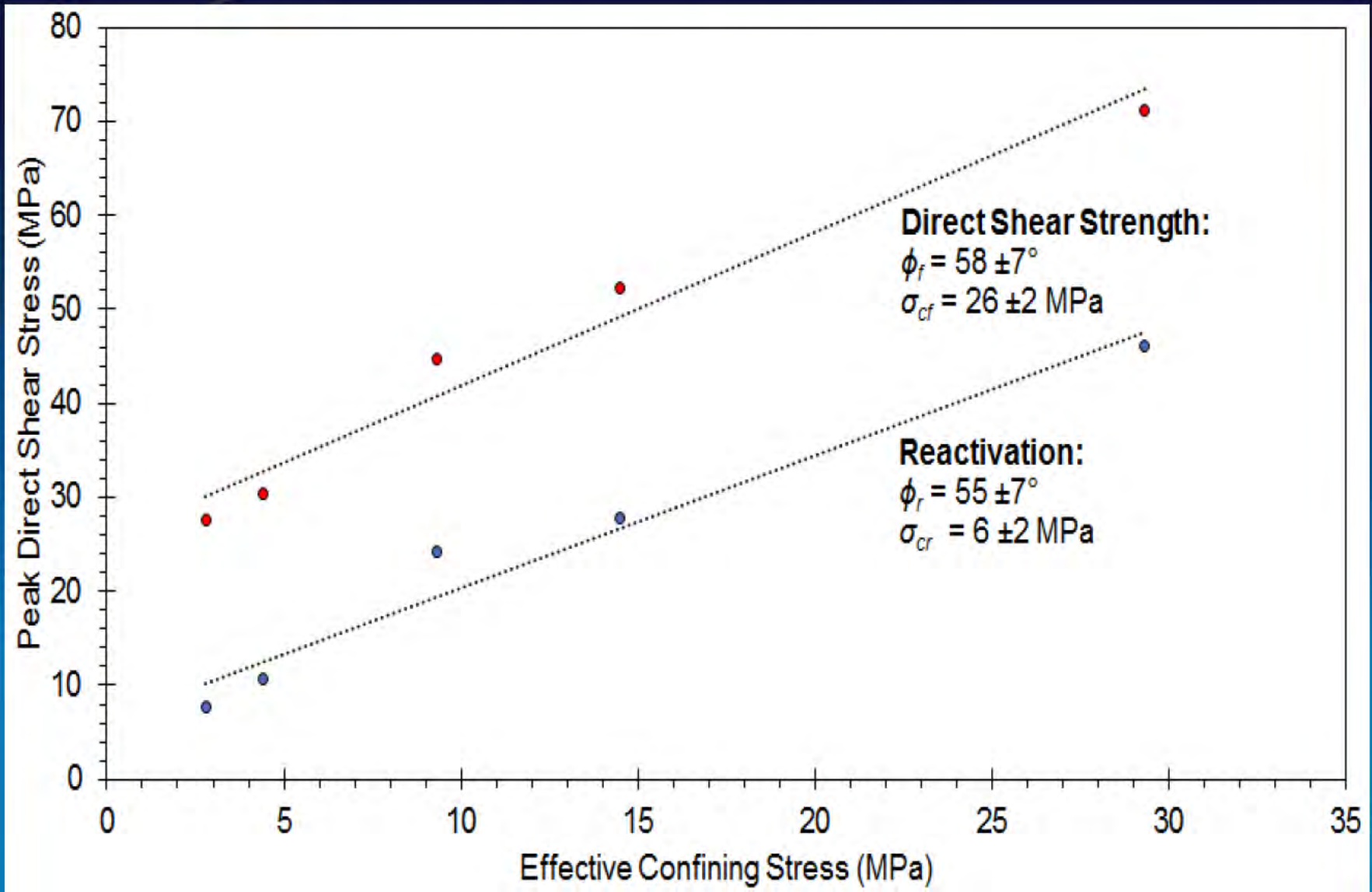


Marcellus Shale Radiography

Carbonate Facies

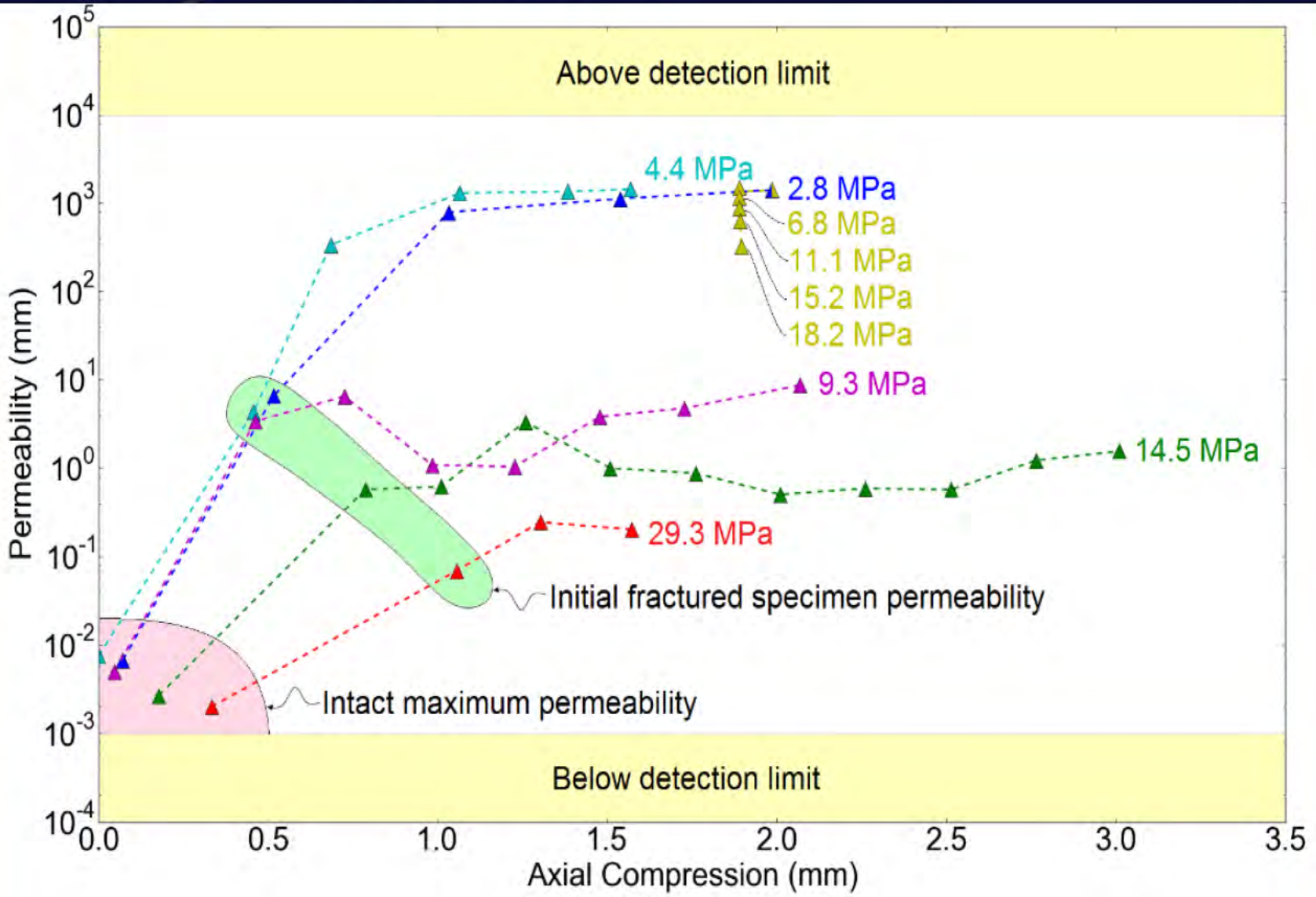


Marcellus Shear Strength



Marcellus Shale Summary

Carbonate Facies



Conclusions

- Direct shear method provides reproducible fracture permeability data and images of fracture apertures
- Low confining pressure
  - Large apertures
  - Permeability increases 5-6 orders of magnitude for carbonate-rich Marcellus
- High confining pressure
  - Smaller and distributed apertures
  - Permeability increases 2-3 orders of magnitude for carbonate-rich Marcellus
- Effect of pressure of fracture creation more significant than subsequent reactivation or changes in effective stress
- Fracture permeability may be bounded as confining stress increases

Carey et al., J. Unconv. Oil & Gas Res., 2015

Frash et al., JGR, 2016

Frash et al. IJGGC (submitted)

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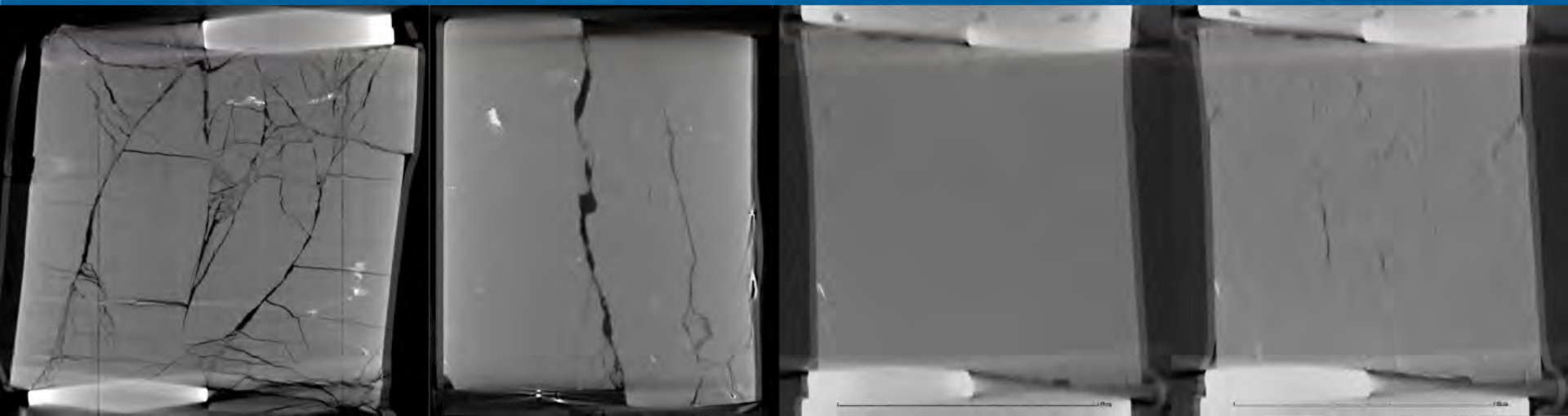

Marcellus Shale Summary

Carbonate Facies