60th U.S. Rock Mechanics Geomechanics Symposium
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Hydraulic Fracturing: Lessons from Experience and Directions for the Future

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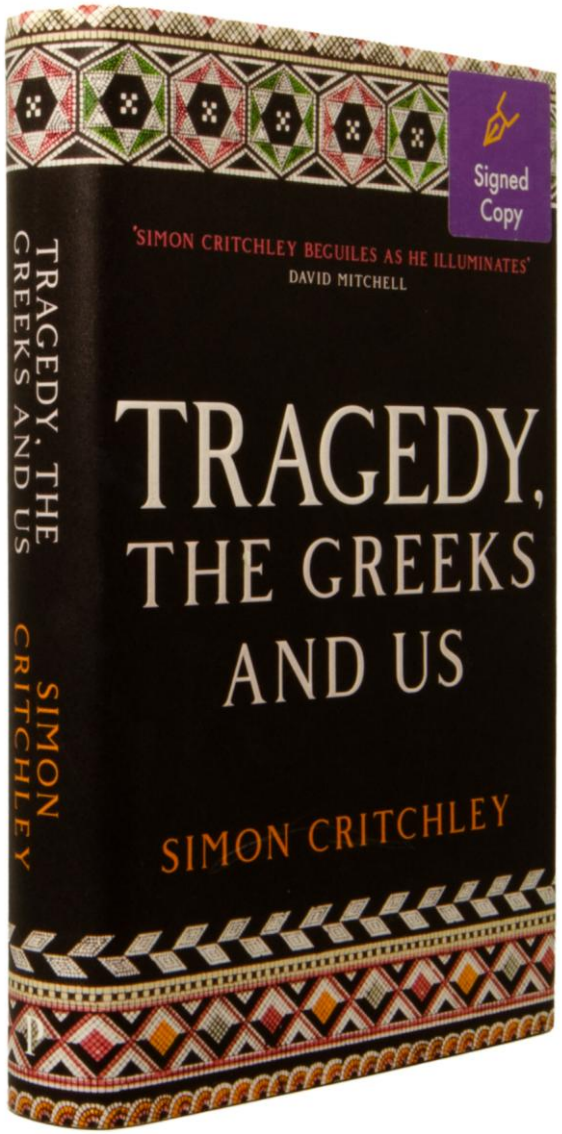
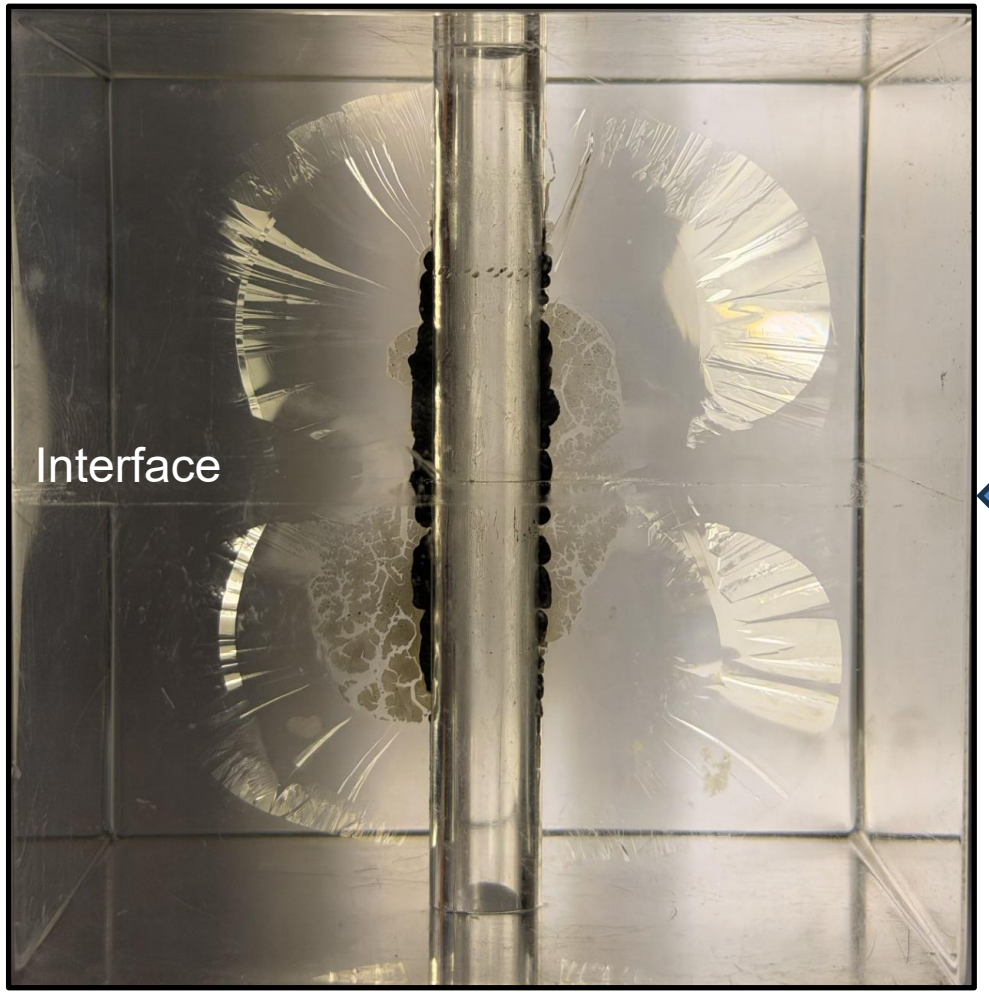
ARMA 26 – 0777

The Past: Hydraulic Fracturing



We may think we are through with the past,
but the past isn't through with us!

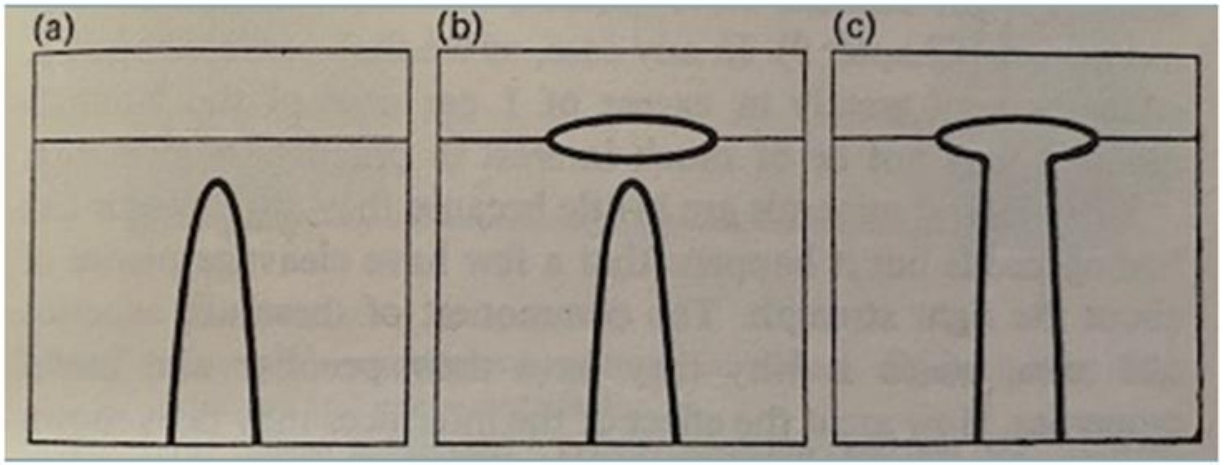
The Past: Fracture in Lucite Block



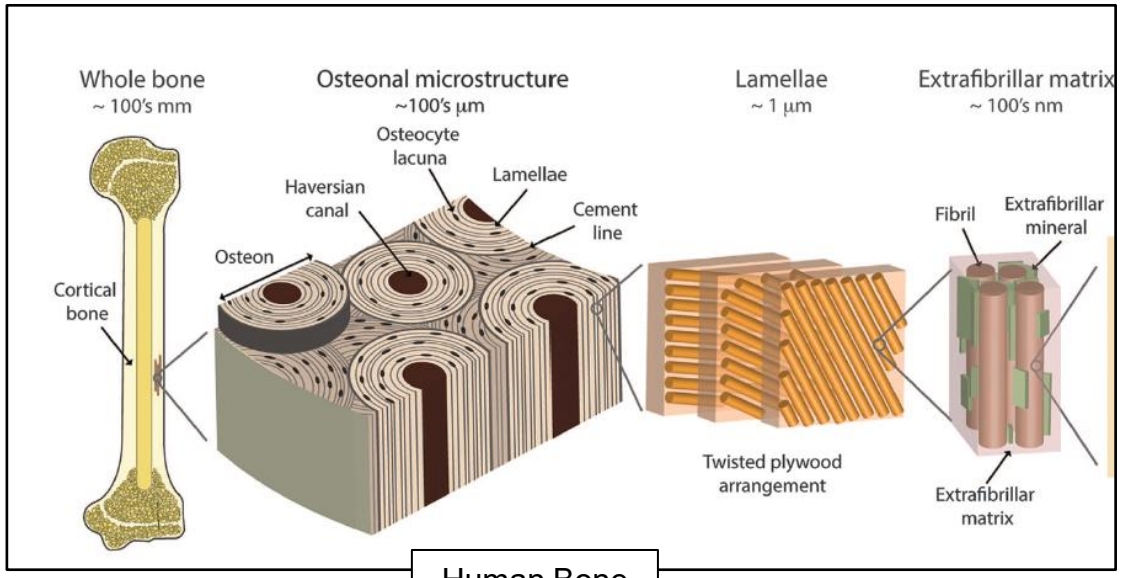
Stable hydraulic fracture propagation (using high viscosity fluid) in a Lucite block containing and interface (1994).

Roberto Suarez-Rivera, 1994 – Class experiment University of California Berkeley

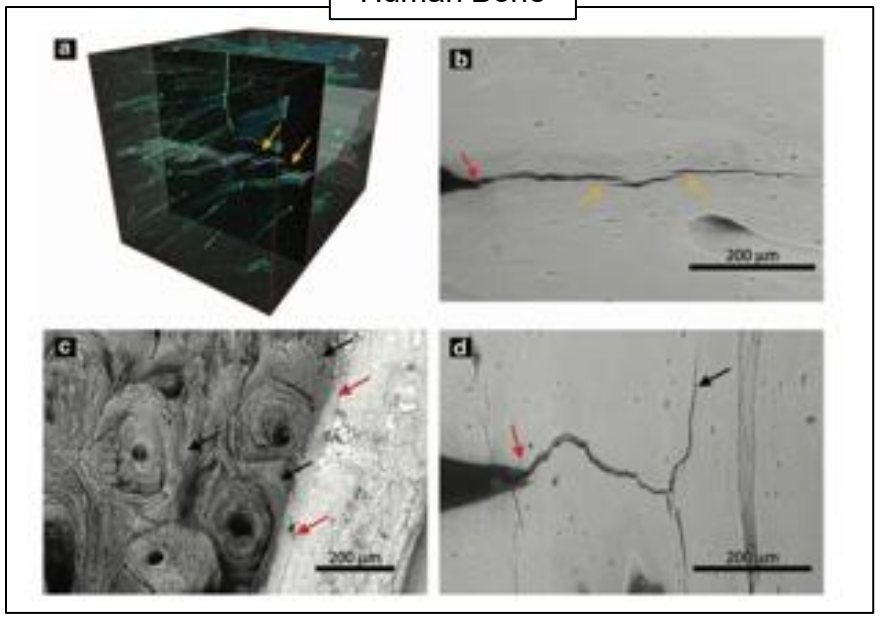
The Past: The Effect of Interfaces on Fracture Propagation



Source of Toughness in brittle materials
J.E.Gordon, 1941.



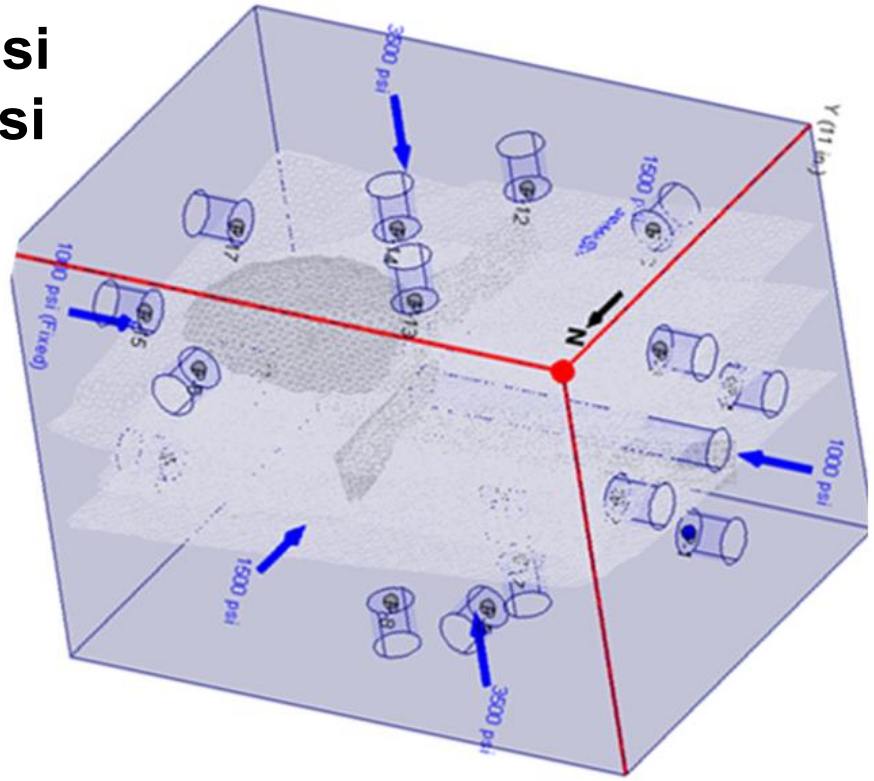
Human Bone

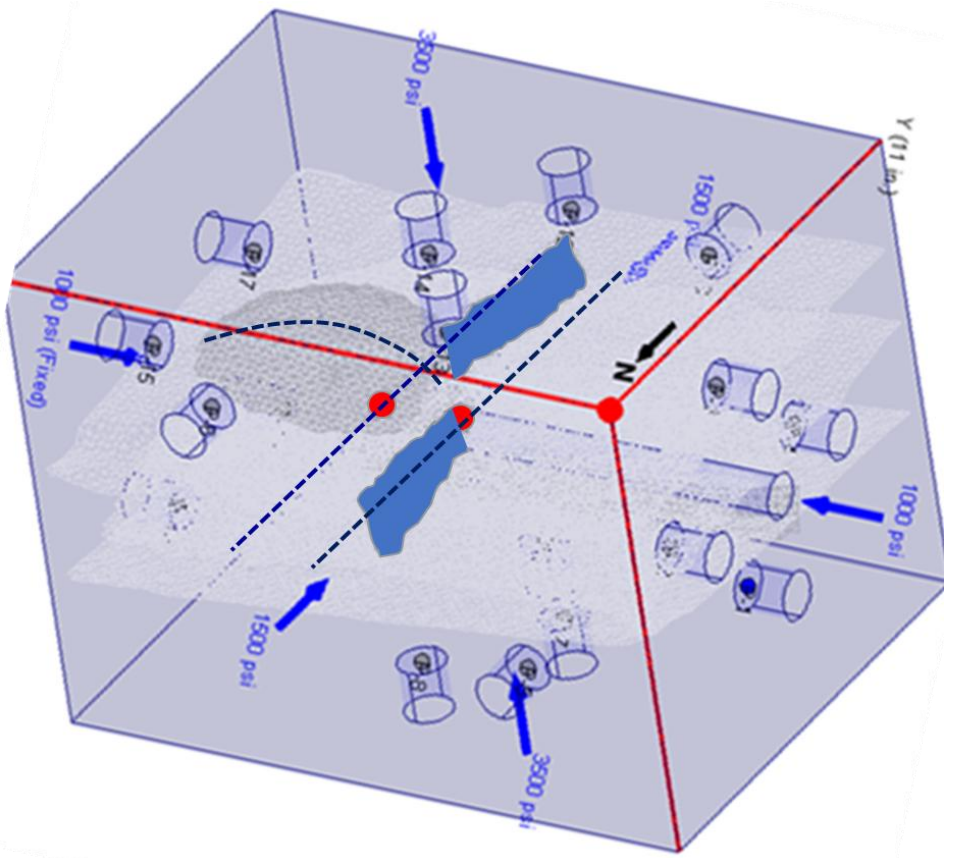


Elizabeth A Zimmermann et al,. 2015

The Past: Fractures in Mancos Shale

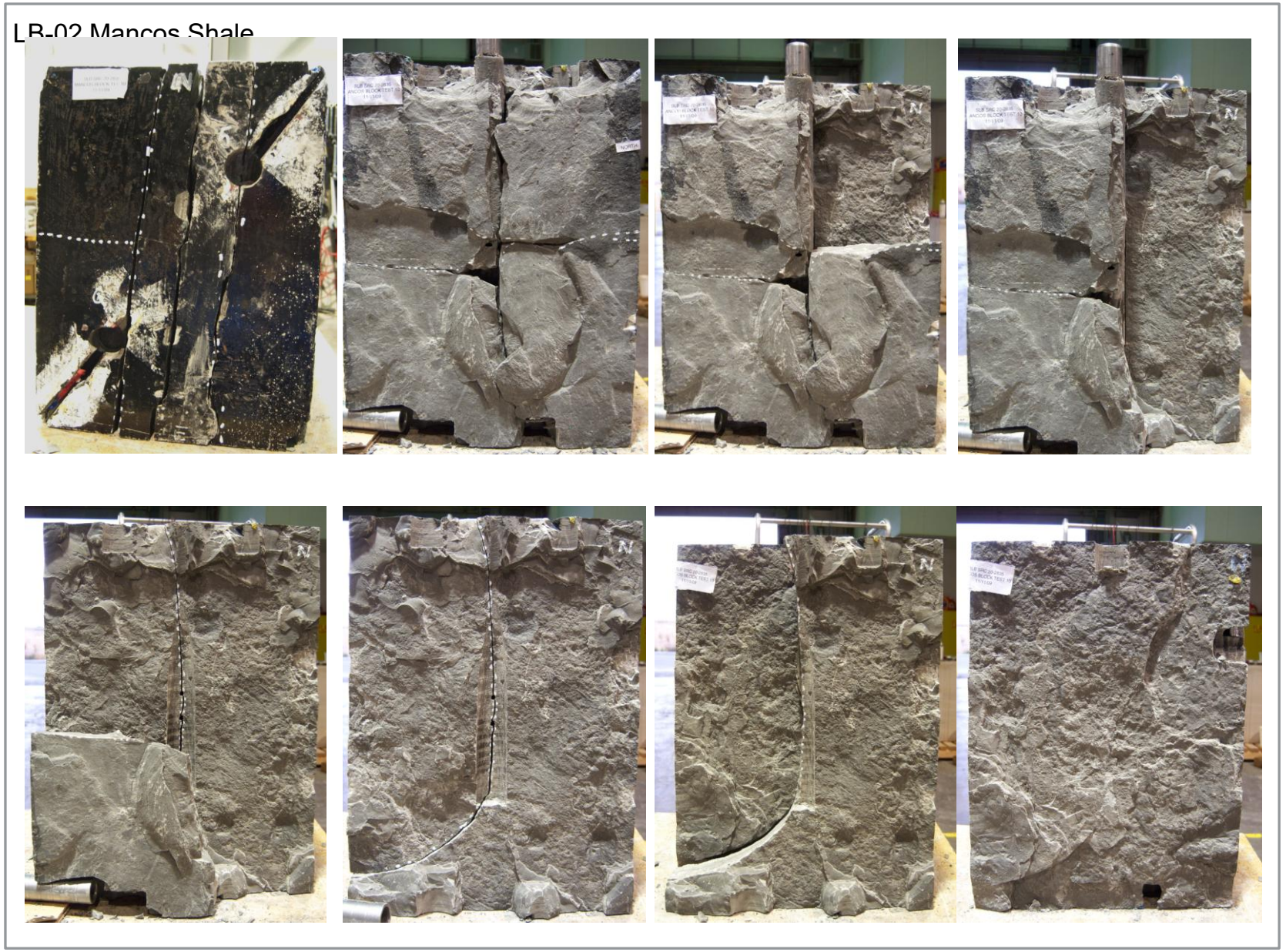
σ_V = 3000 psi
σ_H = 1500 psi
σ_h = 1000 psi





Roberto Suarez-Rivera, 2013 - SPE Workshop on Hydraulic Fracture Mechanics Considerations for Unconventional Reservoirs, Rancho Palos Verdes, CA

The Past: Fractures in Mancos Shale

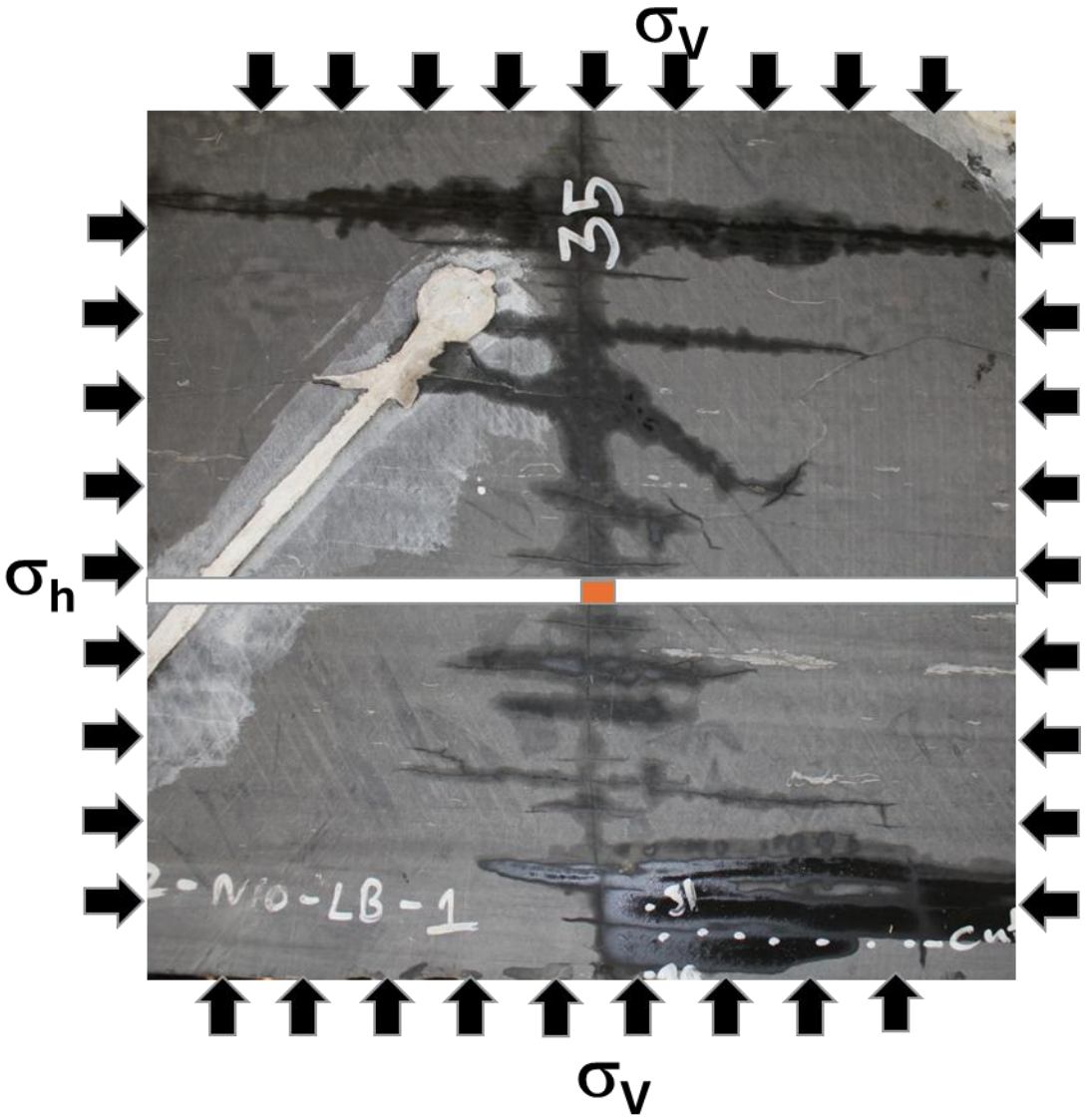


Roberto Suarez-Rivera, 2013

The Past: Large Block Testing (Niobrara Shale)

TerraTek 2014

The Past: Large Block Testing (Niobrara Shale)

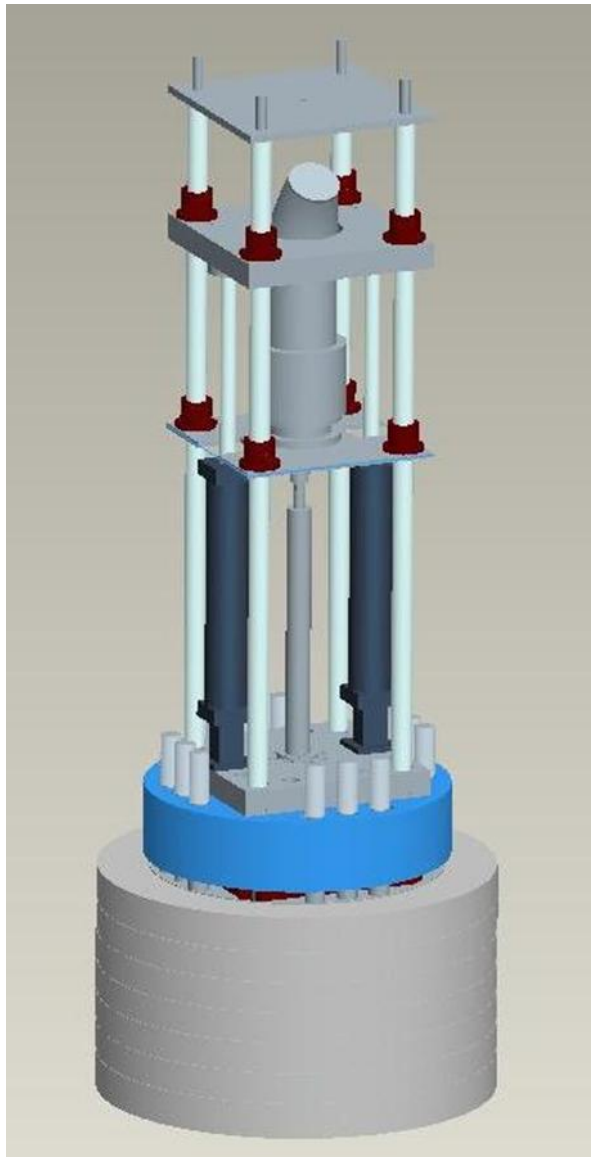


IPTC-17018 • The Effect Of Rock Fabric On Fracture Complexity • Beijing, China 2013

SPE166505• Regions of hydraulic fracture connectivity• R. Suarez-Rivera (2013)

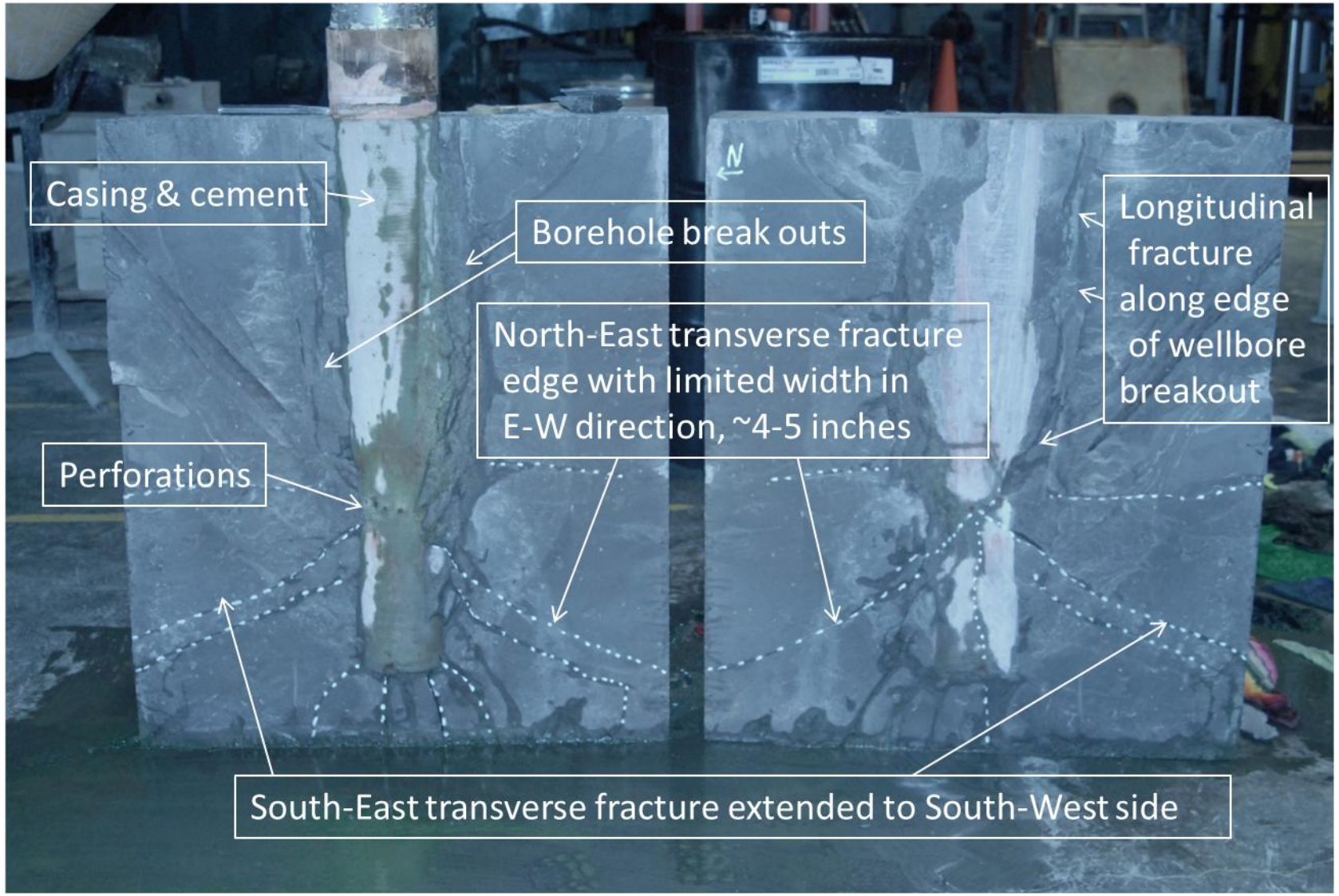
The Past: Large Block Testing (Niobrara Shale)

The Past: Near-Wellbore Effects (Mancos Shale)



TerraTek 2010

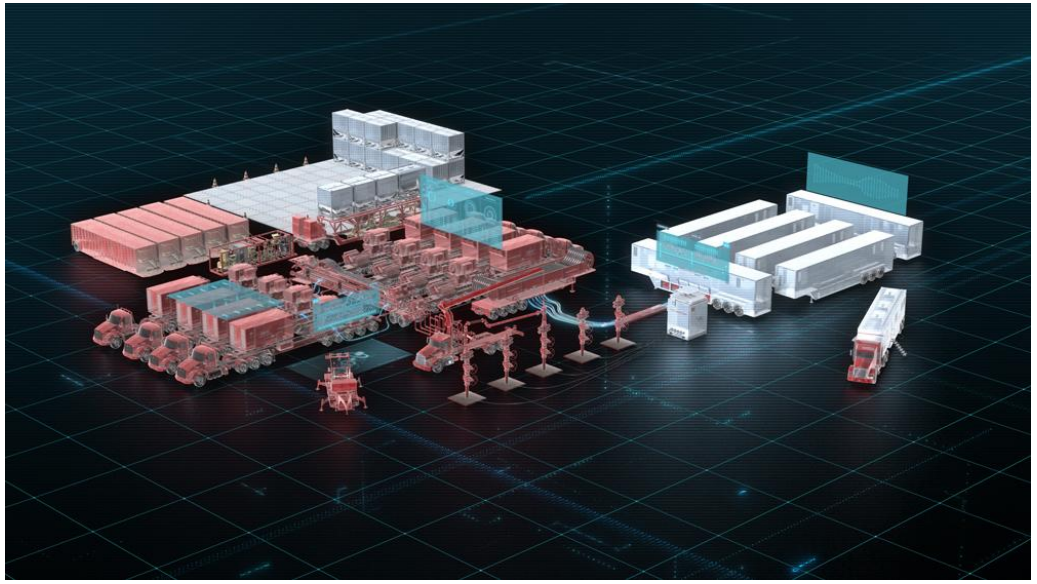
The Past: Near-Wellbore Effects (Mancos Shale)



L. Behrmann, 2010

The Future: Field Practices

- Electrification of surface equipment, combined with closed-loop automation, will deliver a level of execution precision and stage-to-stage repeatability that the industry has never achieved
- This effectively provides operational homogeneity
- Understanding the differences in field measurements (treatment pressure, microseismic and fiber optics data, near-wellbore data and others) in the context of operational homogeneity may improve our understanding of the system heterogeneity
- Coupling field treatment measurements with associated production data may provide reference guiding trends for the treatment



Public web image

TerraTek 2014

The Future: Hydraulic Fracture Monitoring

- Monitoring technologies — particularly distributed fiber optic sensing — will continue to improve in their ability to characterize near-wellbore behavior and injection-phase cluster efficiency.
- However, effective fracture geometry and proppant distribution — will remain unresolved in the foreseeable future, imposing a hard ceiling on the physical fidelity of computational models regardless of advances in High-power computing or AI.
- The fundamental scientific questions of what the fracture network actually looks like, where the proppant goes, which clusters are actually producing and why, will remain open, and the field would be better served by acknowledging this honestly.
- A game changing development will require volumetric subsurface characterization at the relevant scale to image the spatial variability in stress, rock fabric, pore pressure, rock properties along the lateral at meter-to-tens-of-meter resolution.
- This will make every other problem more tractable: cluster efficiency variability, fracture geometry, proppant distribution, and production heterogeneity all ultimately trace back to the fact that we treat

TerraTek 2014

The Future: Hydraulic Fracture Modeling

- I applaud the developers of coupled reservoir and hydraulic fracture simulators. These two systems work intimately together and cannot be decoupled from one another.
- Advances in computational capabilities should facilitate the development and running speed of these systems.
- Given the uncertainties in the inputs and the non-uniqueness of the “field calibrated” adjustments, it may be more useful to use these powerful tools to investigate what-if-scenarios.
- For example:
  - What is the effect of temperature on our simulations?
  - What is the effect of rock heterogeneity and inelasticity on our simulations?
  - What is the effect of proppant placement on our simulations?
  - What is the effect of the uncertain inputs on our simulations?

THANK YOUFOR YOUR ATTENTION

Questions?