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Integrated Geomechanics and Geophysics in Induced Seismicity: Mechanisms and Monitoring

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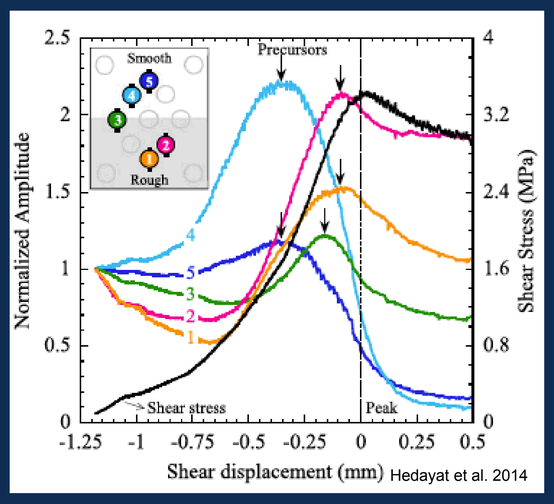
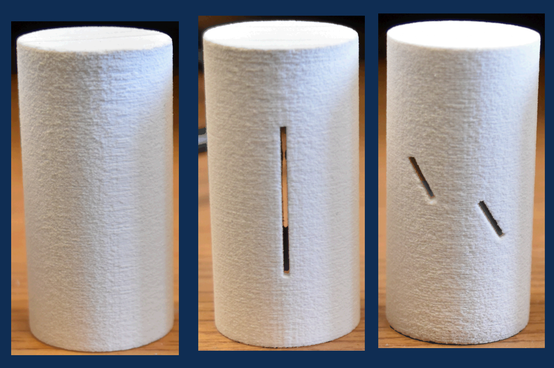
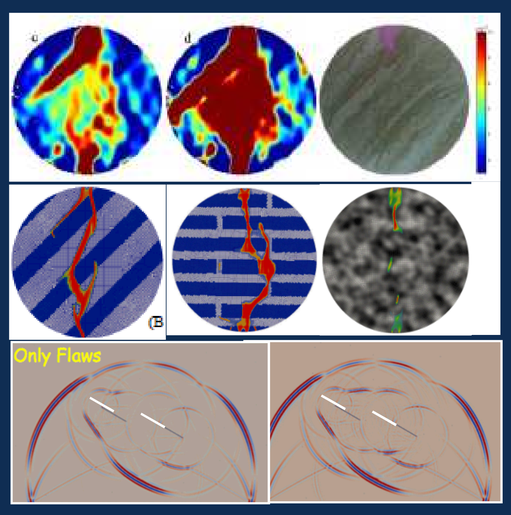
Sandia National Laboratories



Hedayat et al. 2014





Exceptional service in the national interest

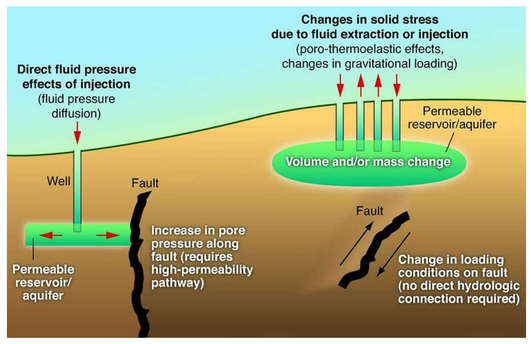
Science Challenges & Objectives

An ambitious integration of seismic imaging experiments coupled with micro-CT imaging, modeling of fracture initiation and propagation, and full waveform inversion will allow us to

(1) delineate crack initiation, propagation and failure using both active and passive seismic/ultrasonic monitoring techniques

(2) determine the mechanical failure mechanisms that lead to induced seismicity from crack propagation and the best seismic imaging modality & precursors to the slip

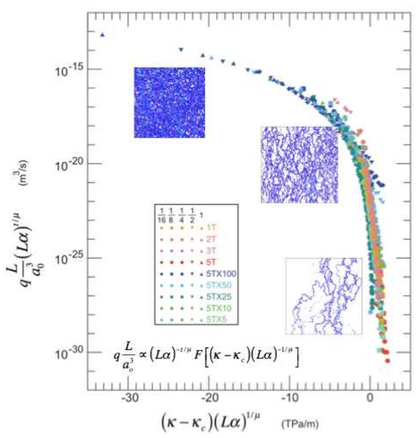
Induced (human-caused) seismicity



http://earthquake.usgs.gov/Research/induced/modeling.php

Flow-Fracture Stiffness, Fracture Length Scale

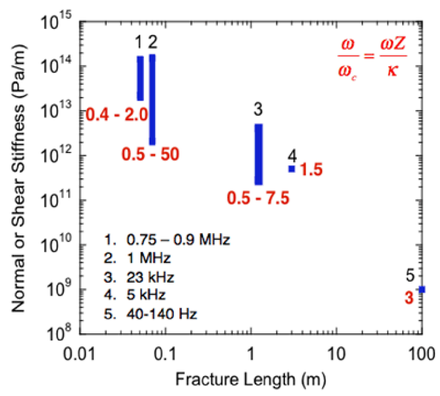
Precursor(s) to the induced seismicity from existing fracture systems - linking mechanical discontinuities, fracture mechanics, pore pressures and stress to the geophysical signatures – is key, yet remains elusive as a result of the heterogeneity and resulting scale dependence.



Flow-stiffness scaling relationship

(*Pyrak-Nolte & Nolte*, 2016).

A link between fluid flow and the seismic response of a fracture because fracture specific stiffness affects seismic wave attenuation and velocity.



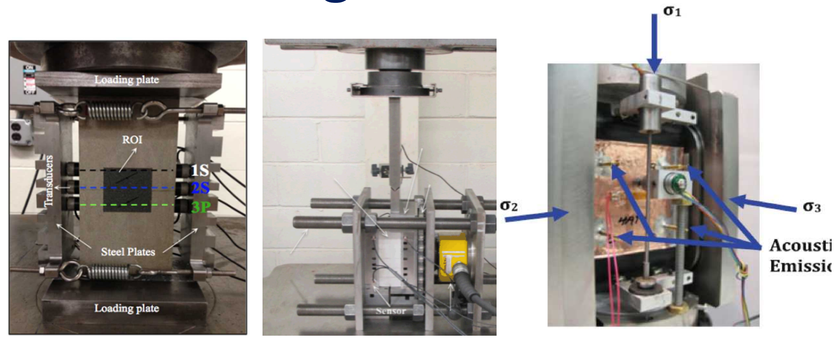
Fracture stiffness-length relationship

(*Pyrak-Nolte @ Purdue*)

No matter what frequency is chosen, some set of discontinuities will be optimal for detection because different wavelengths sample different subsets of fractures.

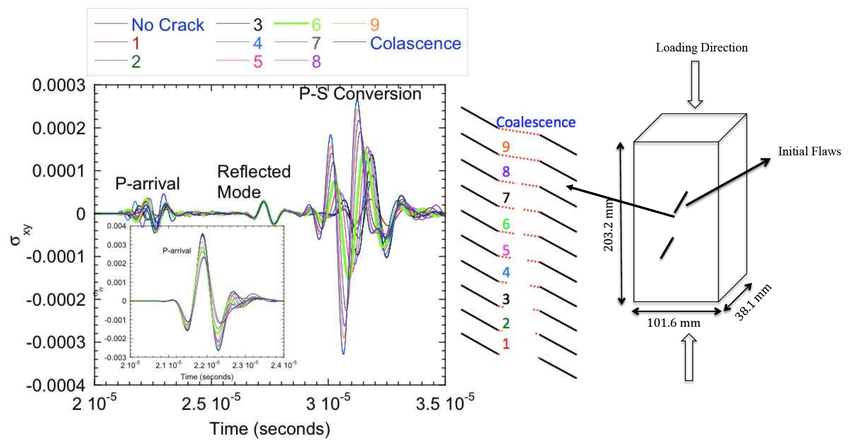
The range of measurability ∝ number of fractures: the additive nature of time delays and the multiplicative nature of transmission/reflection coefficients

Fracturing Testing and Seismic Signal Acquisition



Uni-axial, bi-axial, and tri-axial testing

- Experimental specimens with multiple pre-existing flaws under dry/fluid-saturated P-T conditions
  - Natural rocks (e.g, Indiana Limestone, granite)
  - 3D printed samples (see images below. 1” x 2”)
- Digital image correlation (DIC @ 2.5 µm resolution) and digital volume correlation (DVC @ 15-50 µm resolution) to monitor crack tips for initiation and propagation phenomena of new cracks and coalescence
- Stationary seismic arrays will record the full waveform using both transmitted and reflected waves during loading.



Full waveform measurements with AE and seismic wave transmission/reflection (Hydeyat et al. 2014)

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