Seismic vs Aseismic Slip on Natural Fractures due to Hydraulic Fracturing

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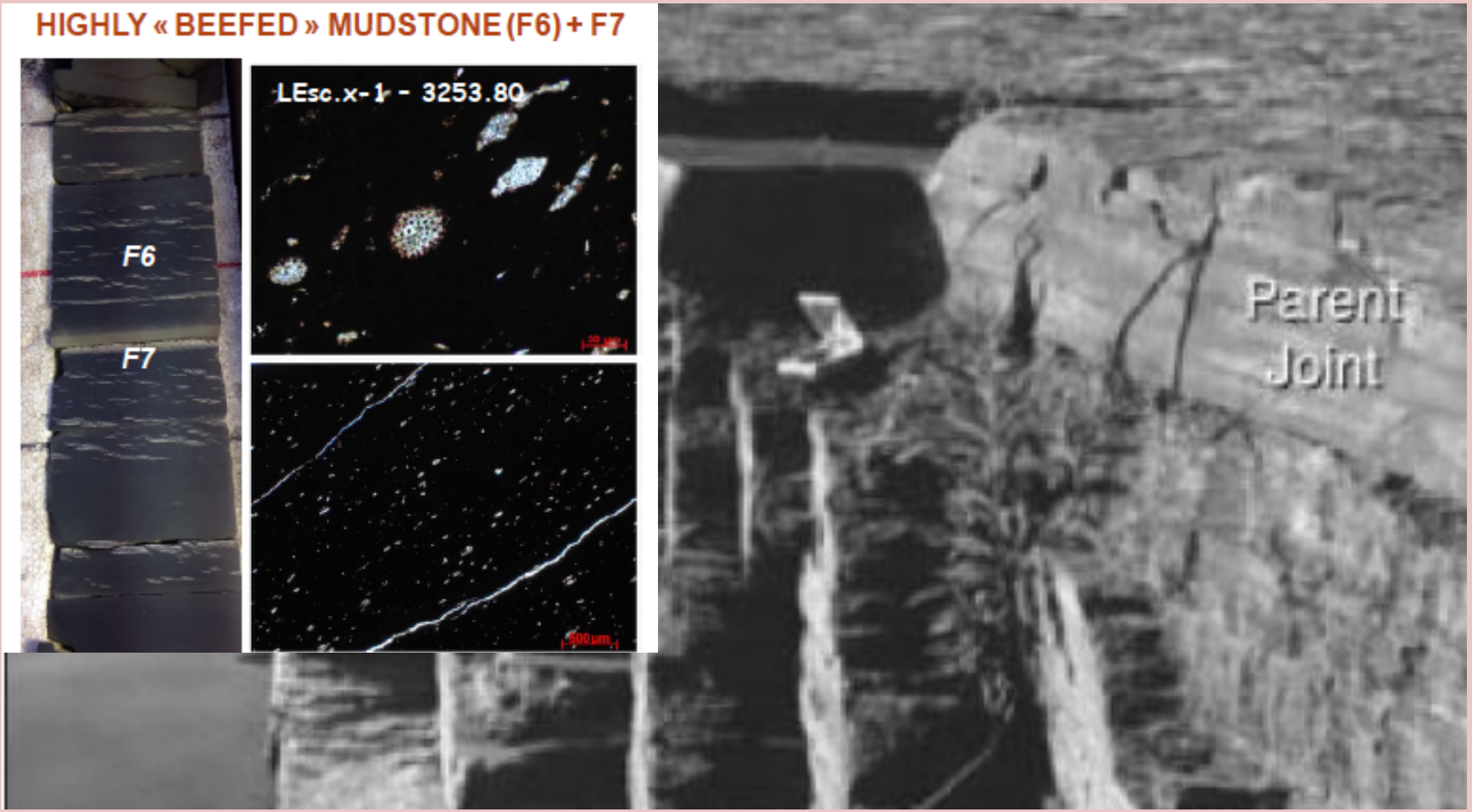
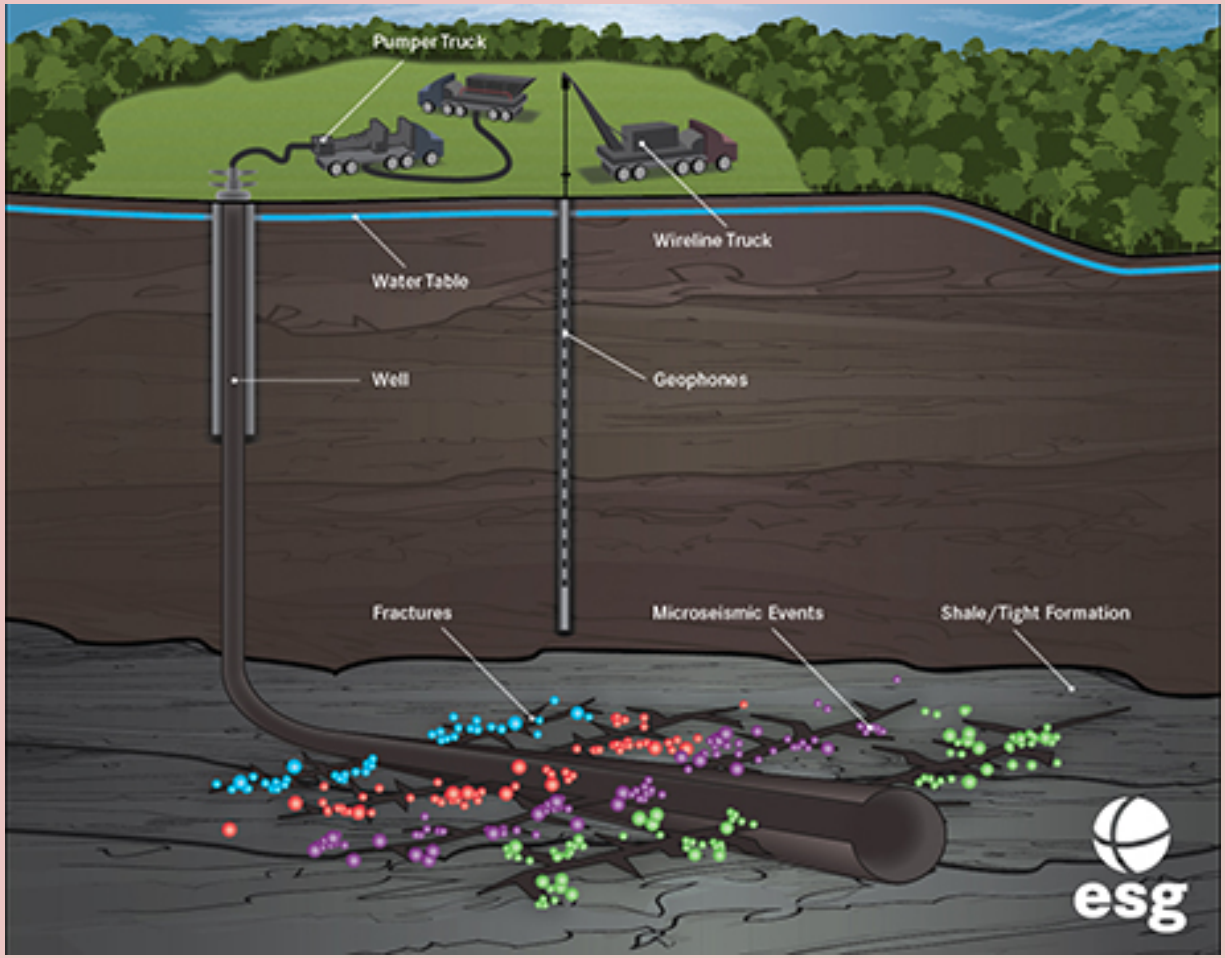
Massachusetts Institute of Technology

Natural Fracture in Shale Formations



Younes & Engelder, *GSA Bulletin* (1999), **111**, **2**, PP. 219-239

Microseism Monitoring



Research Goals

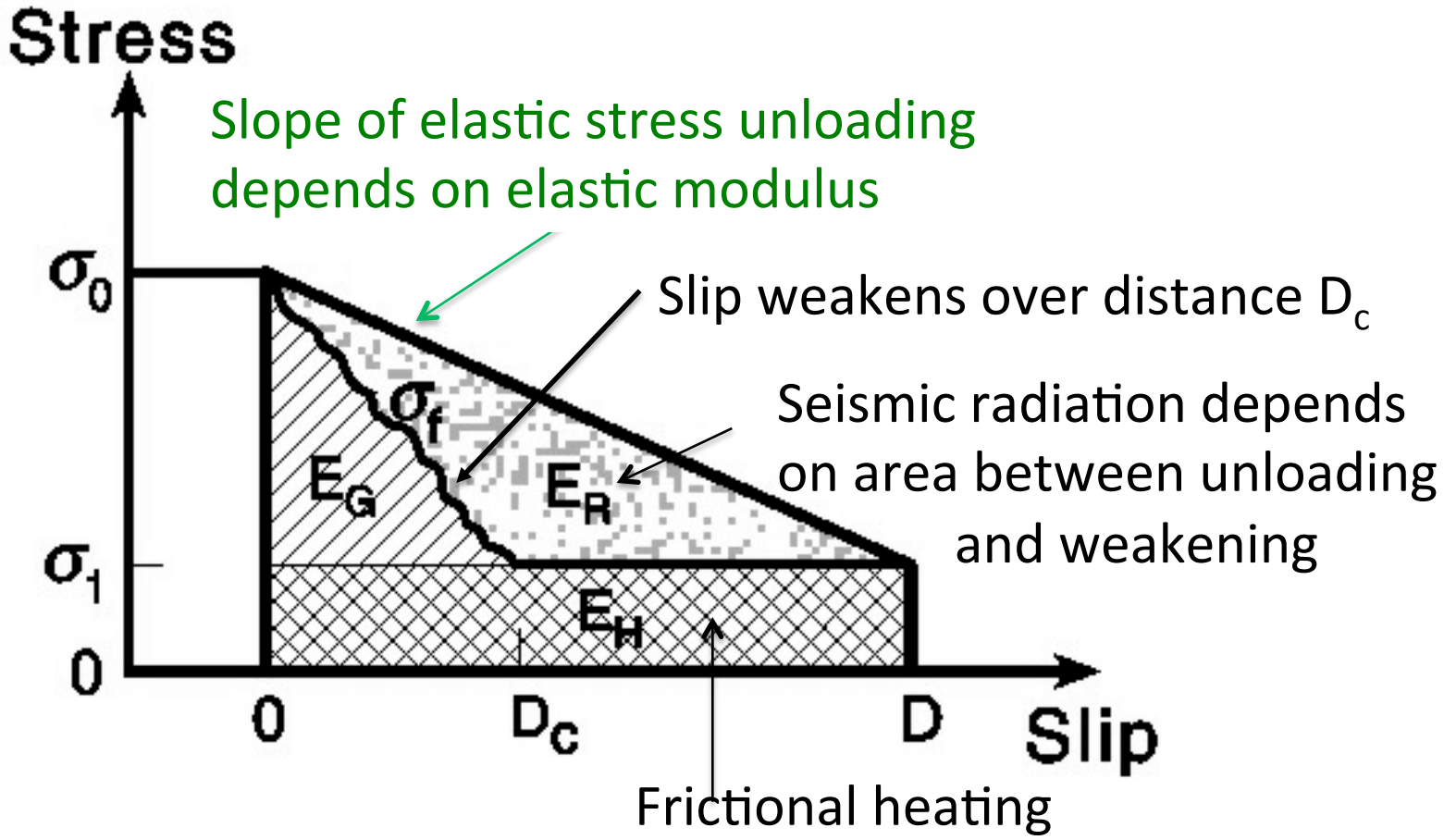
What is microseismicity telling us?

- Existence/absence of fracture slip?
- Amount of fracture slip?
  - Amount of dilatancy?
- Distribution of lithology?

Focus on understanding partitioning of seismic vs aseismic slip in pre-existing natural fractures

- What controls instability (seismic vs aseismic)?
  - Friction law?
  - Plastic yielding?
  - Loading rate?
  - Fracture length?
  - Elastic moduli?

Seismic slip requires slip-weakening



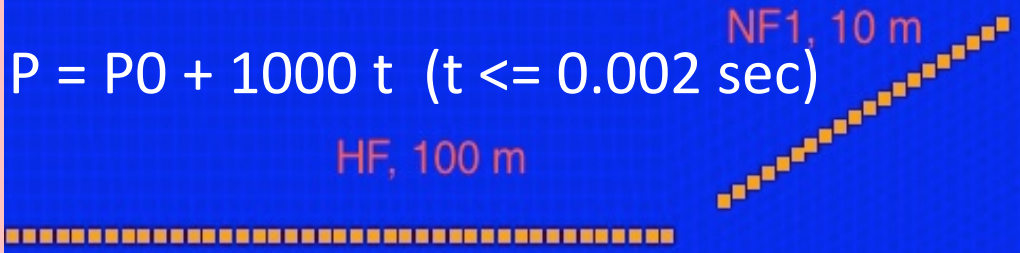
Hydrofracture-Natural fracture interaction (2-D):

Uniform pressure on hydrofracture, background tectonic stress promoting reverse faulting

W = 10 m;
expect M ~ -1, D ~ 0.3 mm

Fast compared to realistic loading and slow compared to rupture and seismic wave propagation

P = P0 + 1000 t (t <= 0.002 sec)

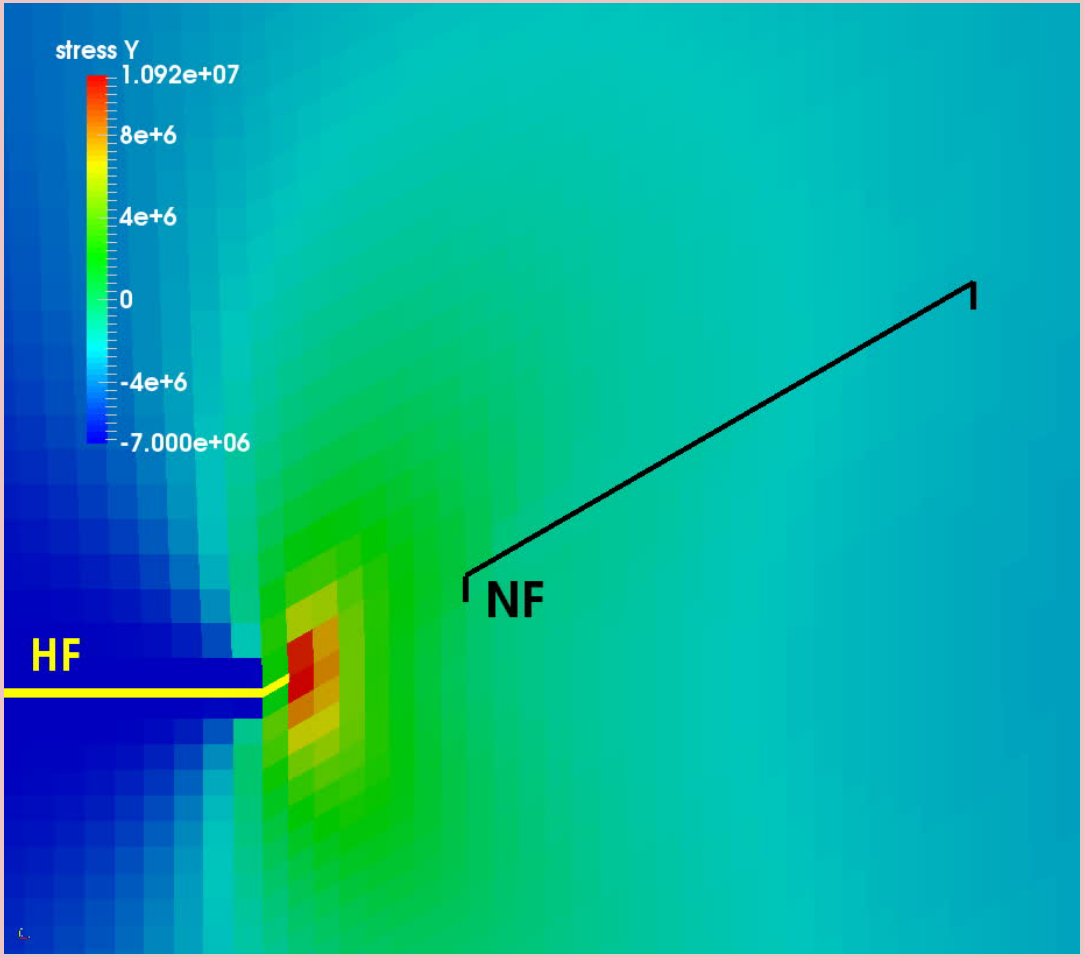


Modulus of Elasticity
20 ,40, 80 GPa

Pore Pressure	Shmax	Shmin	Initial Net Inj. Pressure
25 MPa	33 MPa	30 MPa	2 MPa

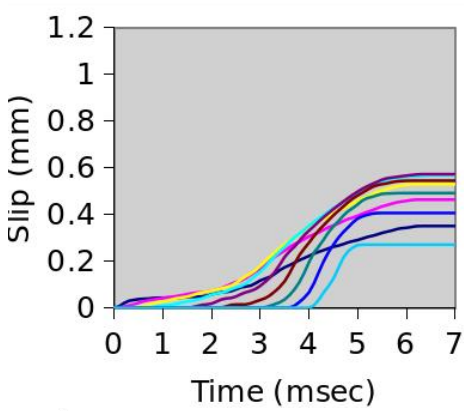
NF Static FC	NF Dynamic FC	Slip-weakening Parameter (mm)
0.7	0.1, 0.4	0.2, 0.1

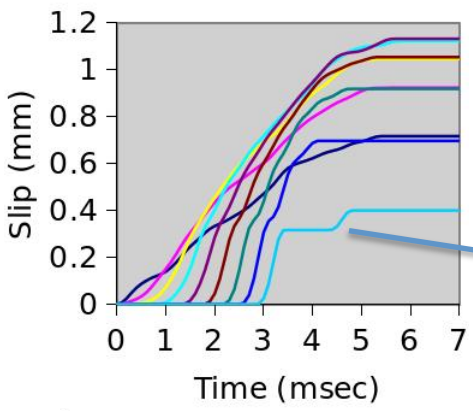
Rupture Propagation dc=0.1 mm, E=20 GPa



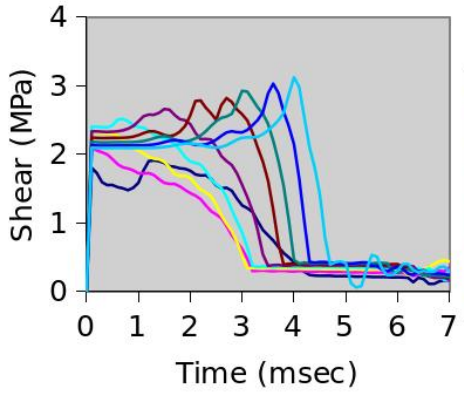
Effect of Shear Modulus on Slip and Shear History

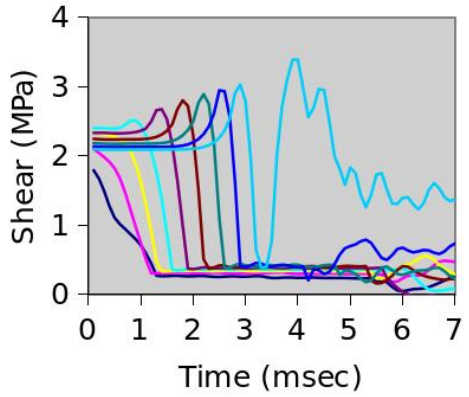
G=32 Gpa, D_c= 0.2 mm, DFC=0.1 **G = 16 GPa, D_c = 0.2 mm, DFC=0.1**

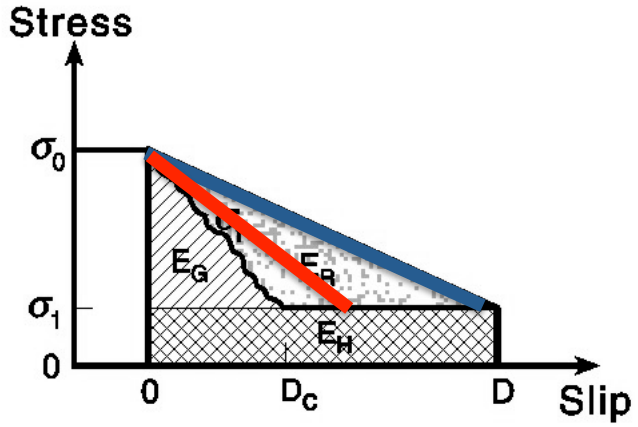




2nd event

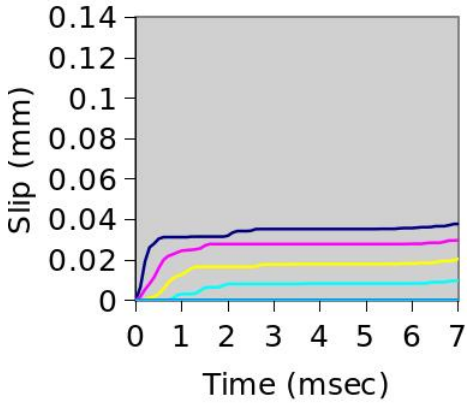




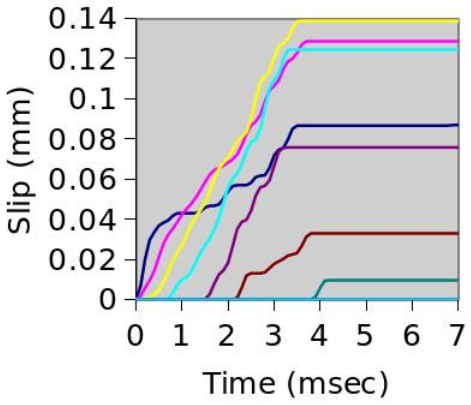


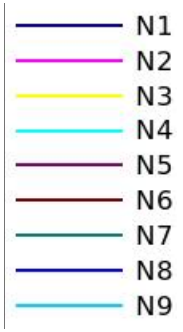
Effect of Slip Weakening Distance on Slip and Shear History

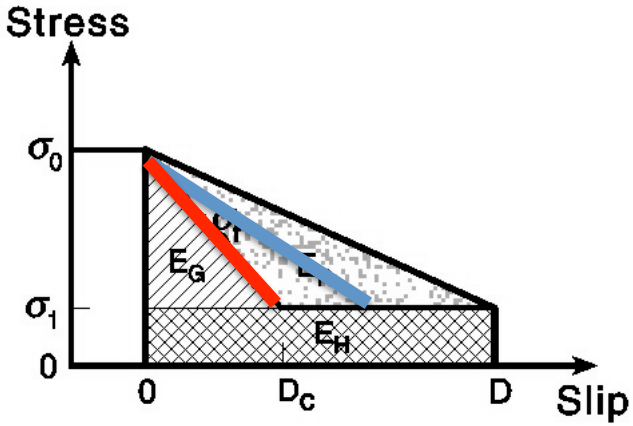
D_c = 0.2 mm, E=80 GPa, DFC=0.4



D_c = 0.1 mm, E=80 GPa, DFC=0.4

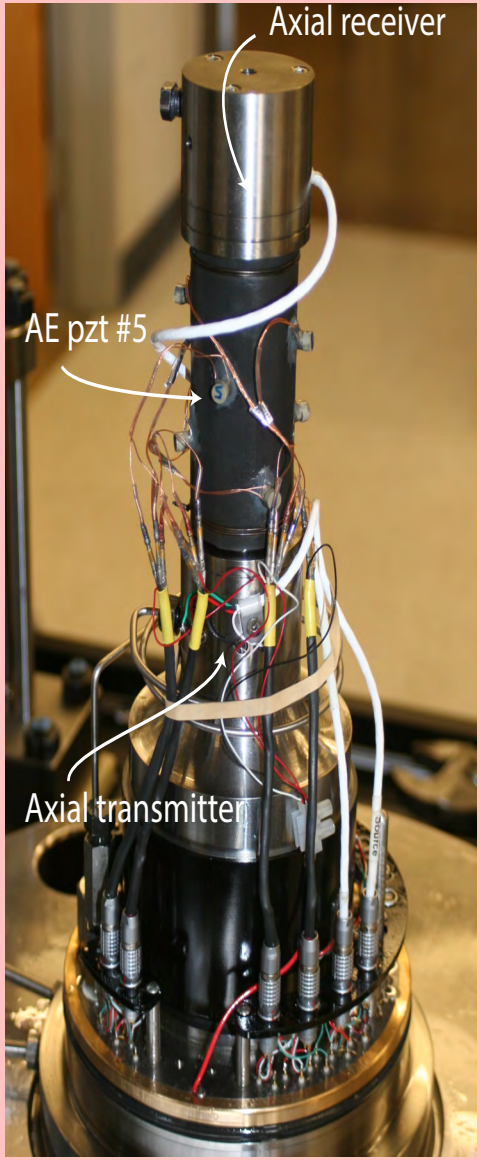


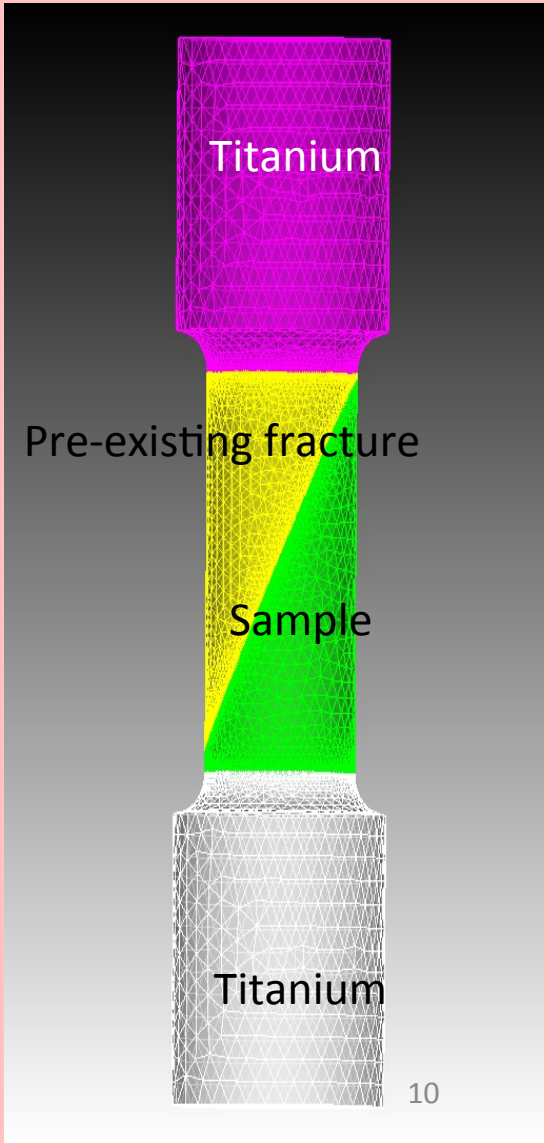




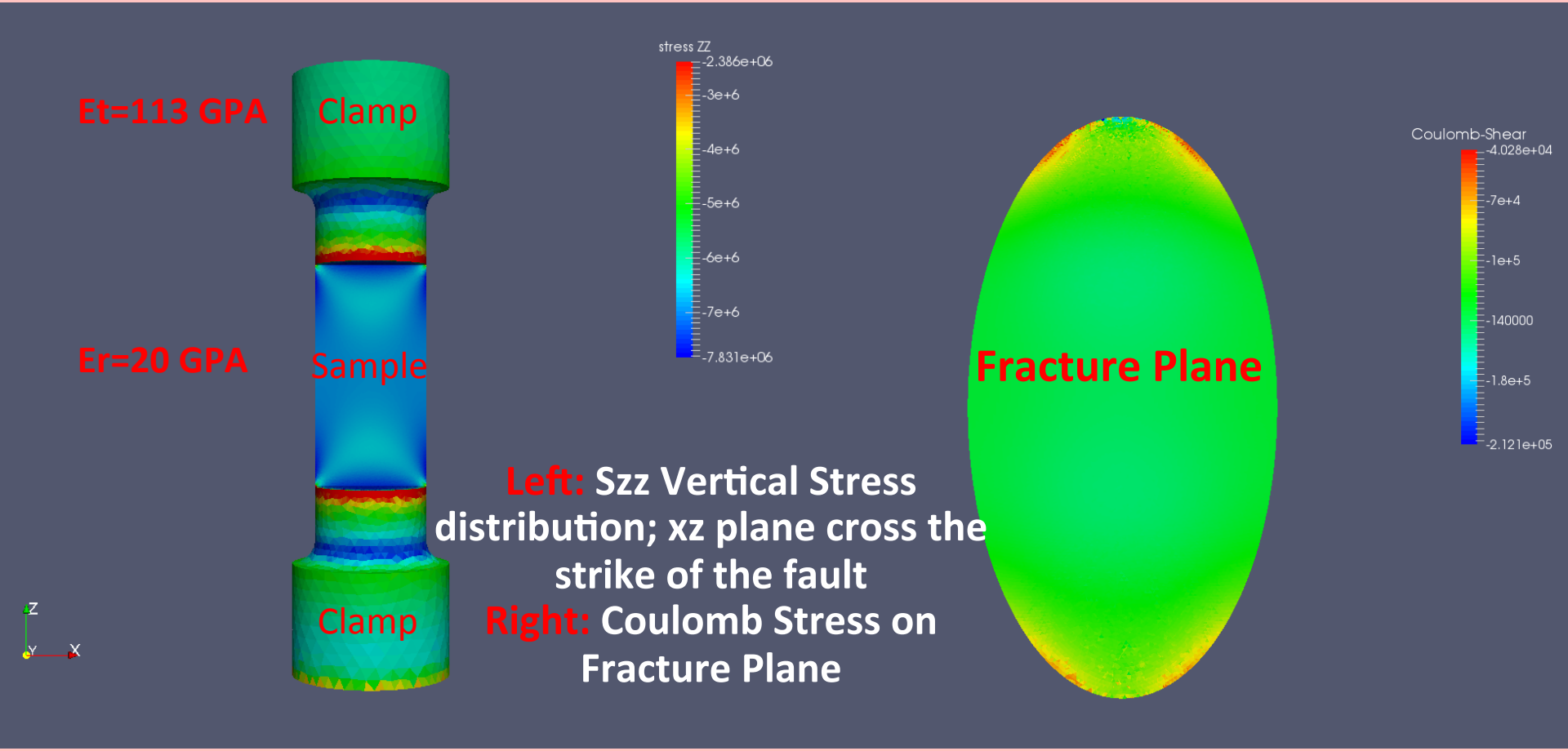
Fault constitutive model as well as rock mechanical properties affect HF induced seismicity. Acoustic emission measurement helps better understanding of fault model and numerical model calibration.

AE Comparison with Lab Experiments and Fault Constitutive Modeling Determination

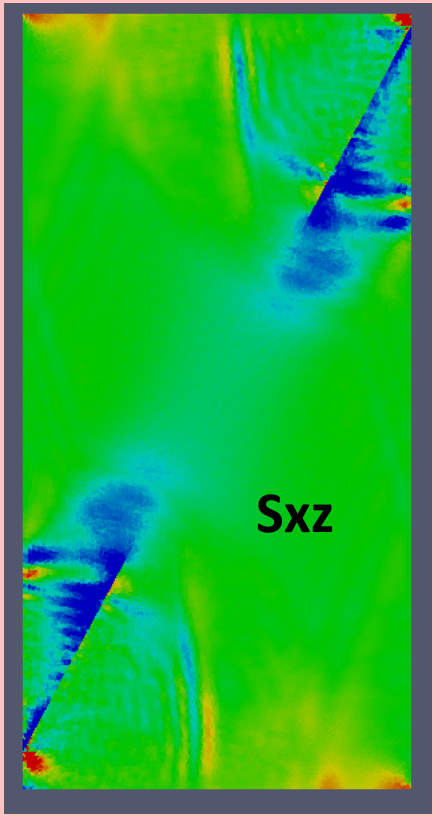


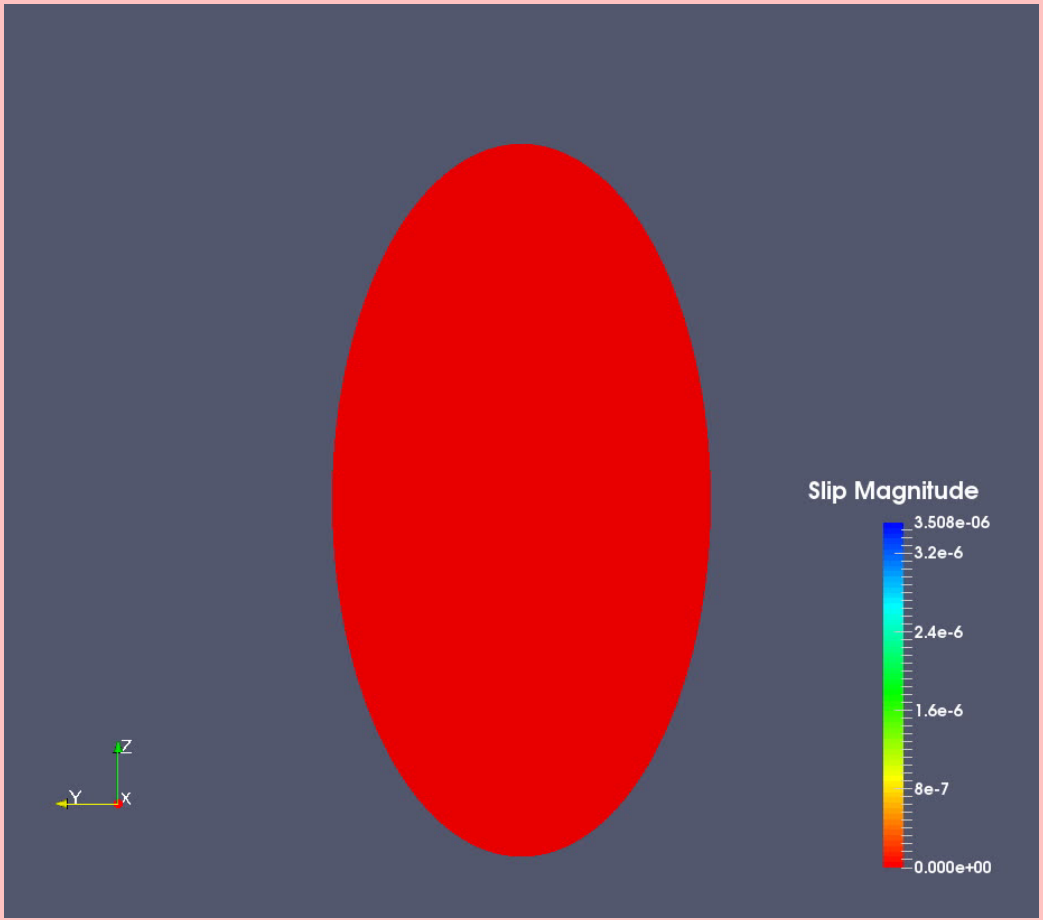


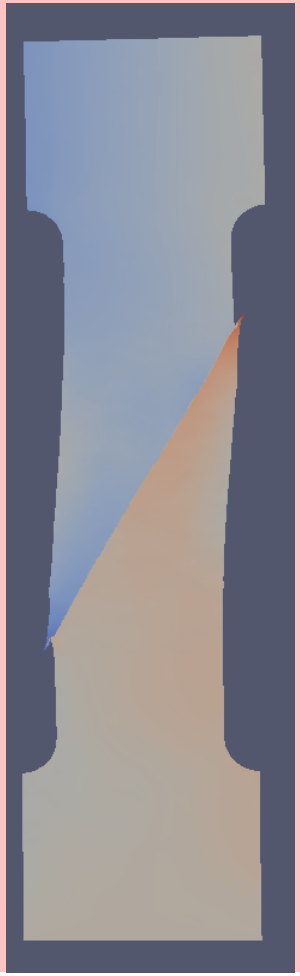
NF Constitutive Modeling; Stress Concentration due to Mechanical Property Miss-match in Triaxial Test



Rupture Evolution and Slip Distribution on Fracture Plane



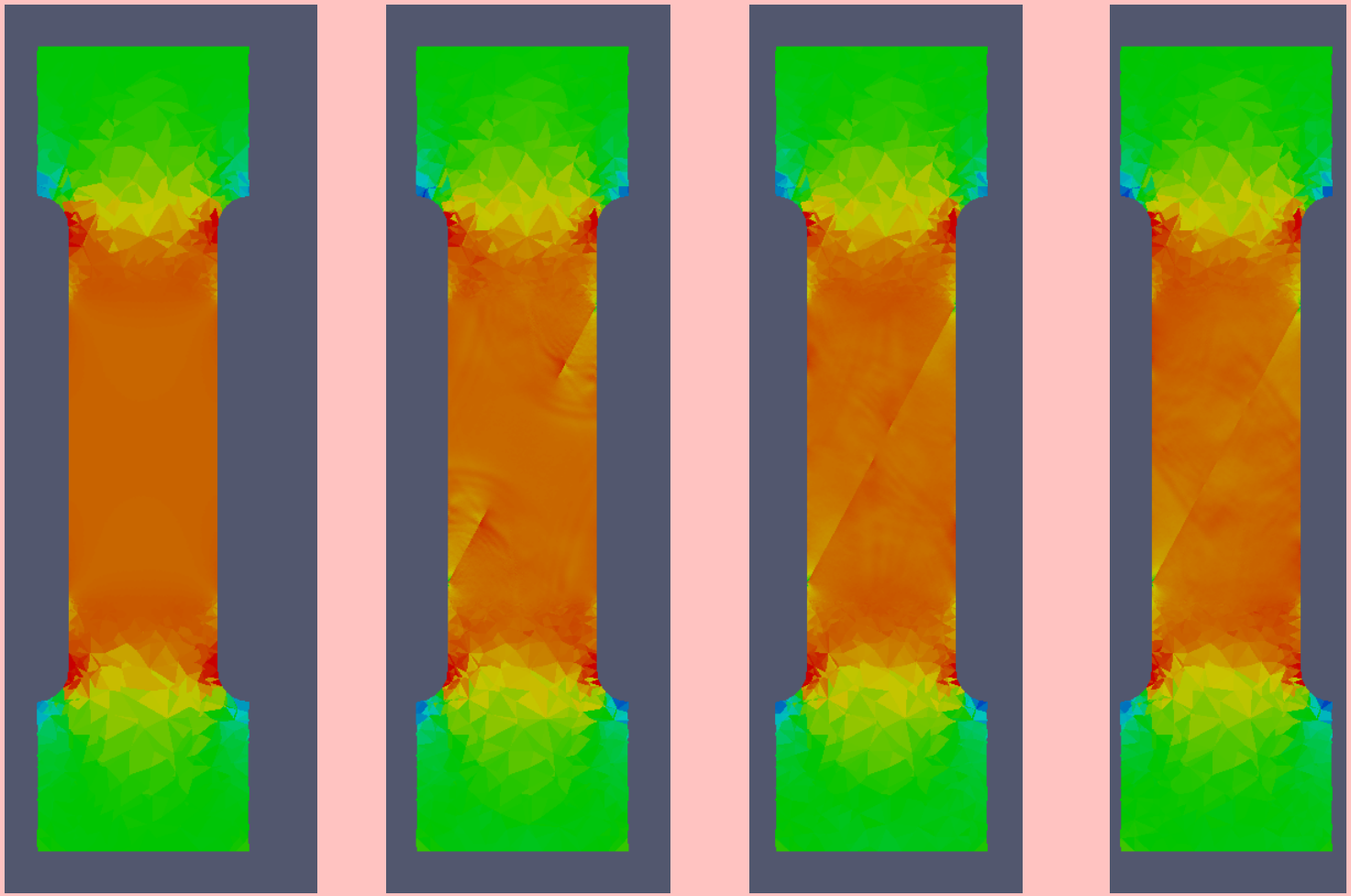




Slip direction down-dip

Rupture propagation downward from the top and upward from the bottom

Rupture Evolution; Vertical Stress on Strike-perpendicular Cross Section



Conclusion

- Natural fracture slipping due to hydraulic fracturing would generate seismic waves.
- Even simple friction law shows interesting effects
  - Lower elastic modulus promotes instability
    - Also higher rupture velocity, greater slip
  - Smaller slip weakening distance promotes instability
    - Affects distribution of rupture
- For fault constitutive modeling and its effect on elastic waves as well as acoustic emission monitoring on lab scale sample, a 3D numerical experiment was made. Further comparisons with AE lab results will lead to understand fault constitutive modeling behavior.

Thank you!