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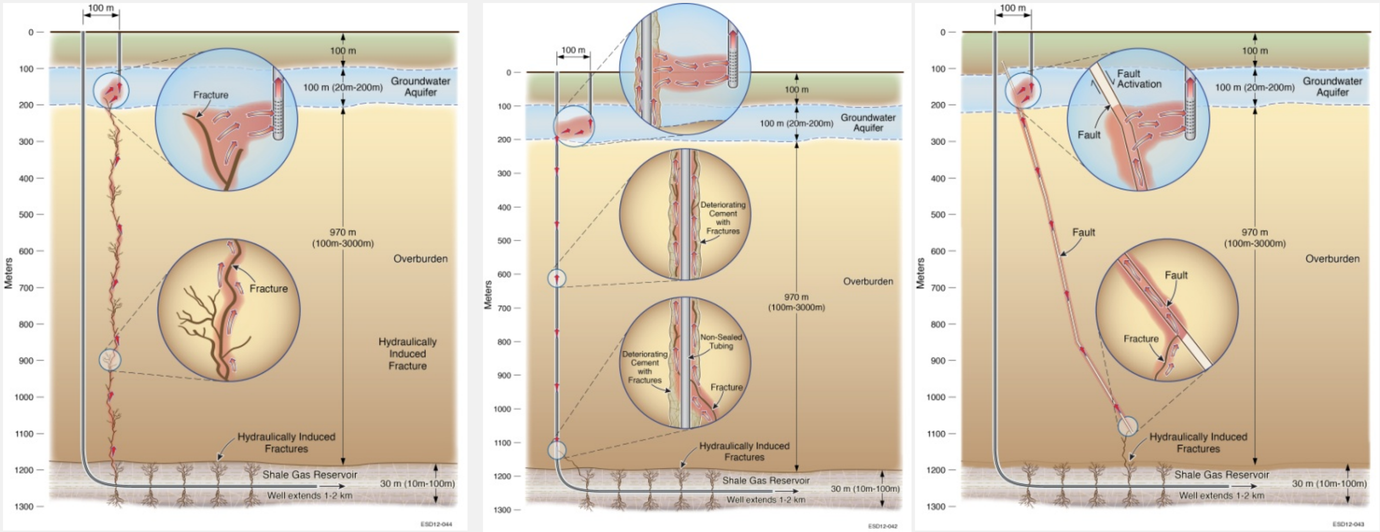
Analysis of Feasibility of Extensive Fracture Development and Fault Activation Induced by Hydraulic Fracturing

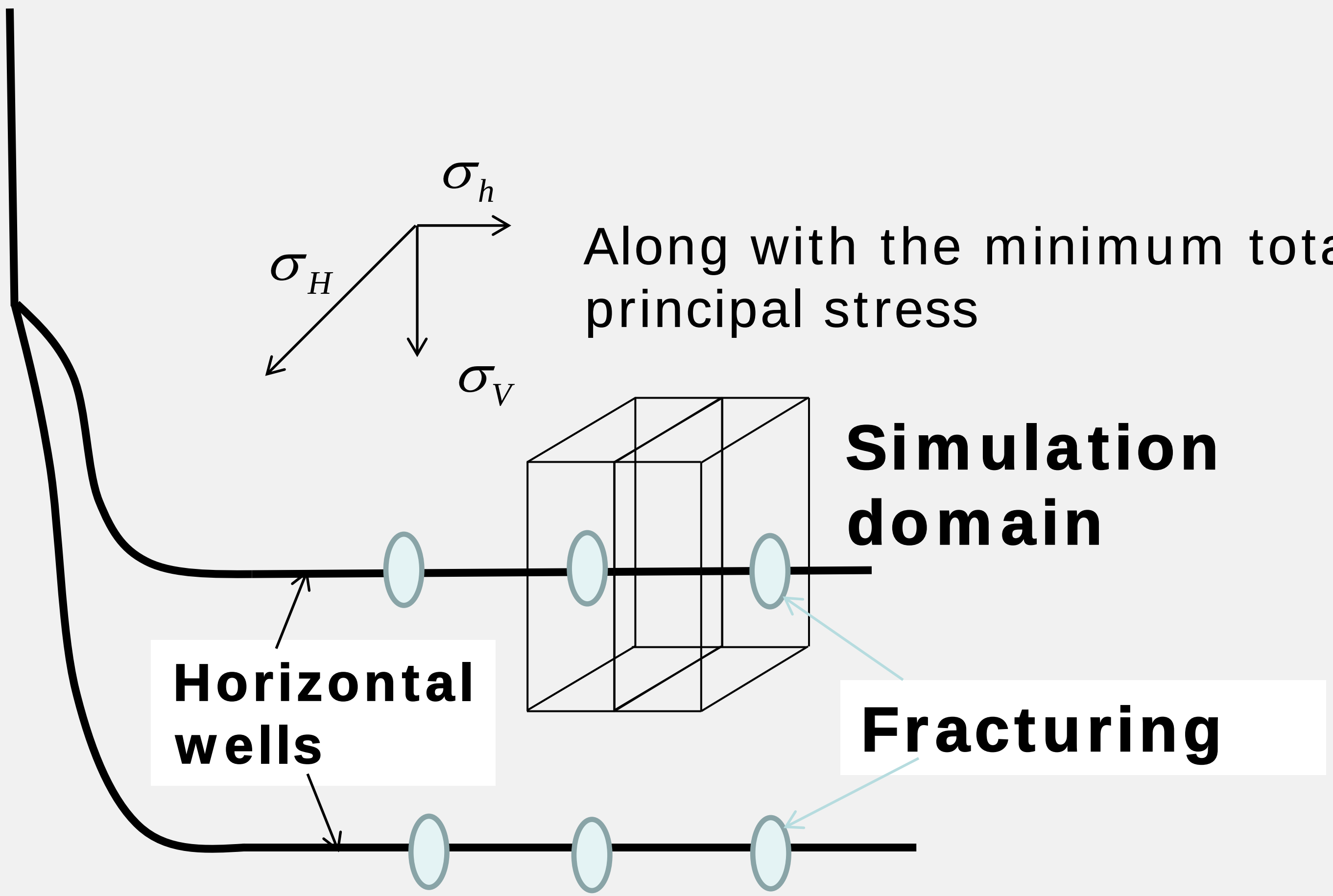
Technical Workshop Series:
Well Construction/Operation and Subsurface Modeling



George Moridis, Jihoon Kim and Jonny Rutqvist, LBNL

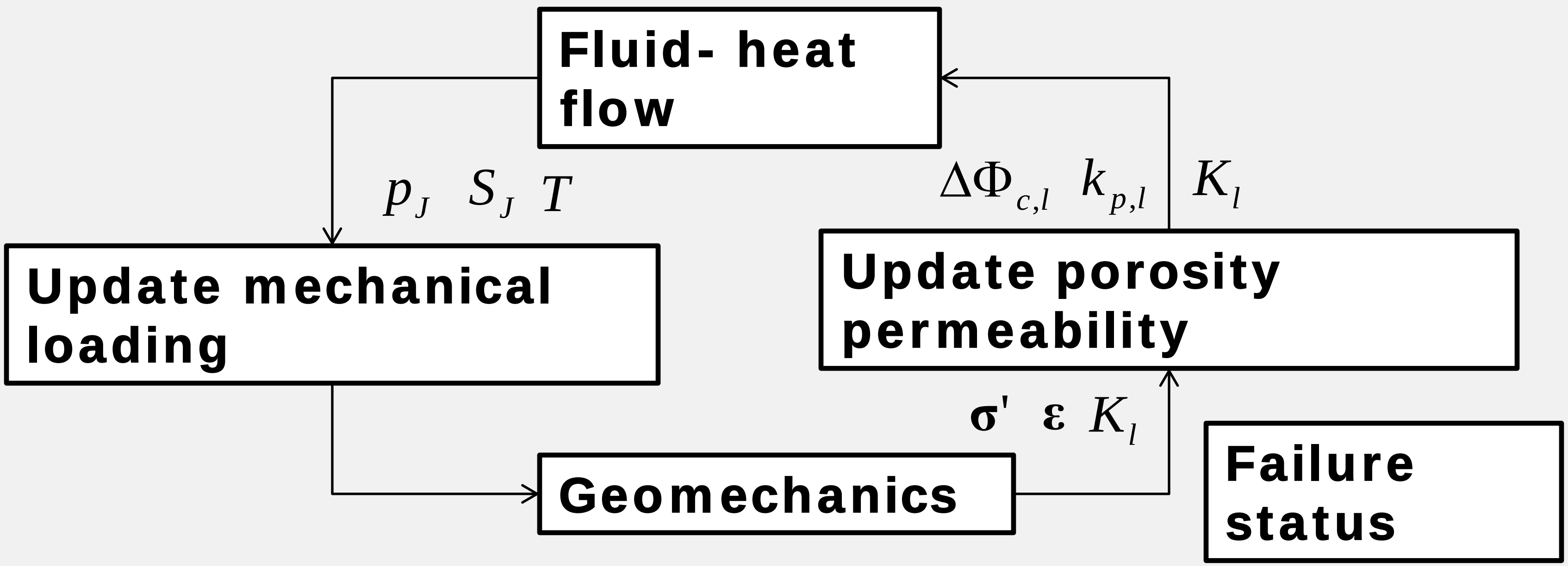
Research Triangle Park • April 17, 2013

Hydraulic Fracturing



Along with the minimum total principal stress

Sequential Implicit Algorithm



Flow: finite volume (e.g., TOUGH+RealGasH2O)

Geomechanics: finite element (e.g., ROCMECH)

Coupled flow & geomechanic simulator, shortly T+M.

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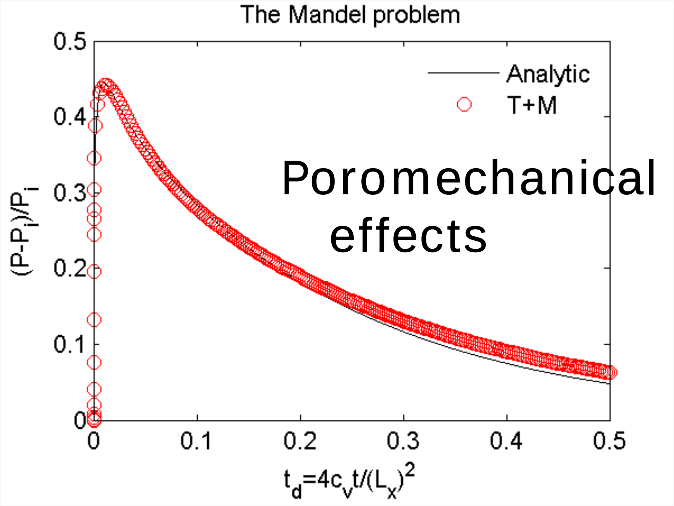
T+M Code

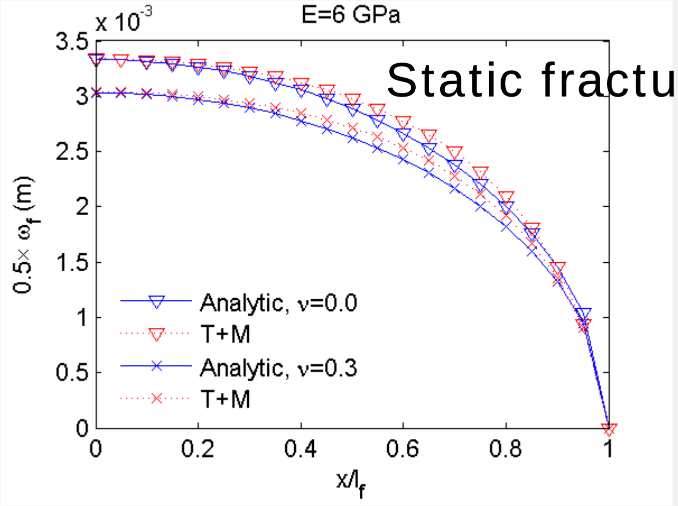
T+M: TOUGH+RealGasH2O+ROCMECH:
Flow + thermal + geomechanical processes
Rigorously coupled Processes

- Thermo-poro-mechanics (two-way coupling)
- Dynamic multiple continuum approach
- Simultaneous tensile & shear failure
- Leak-off to the reservoir formation from full 3D flow simulation

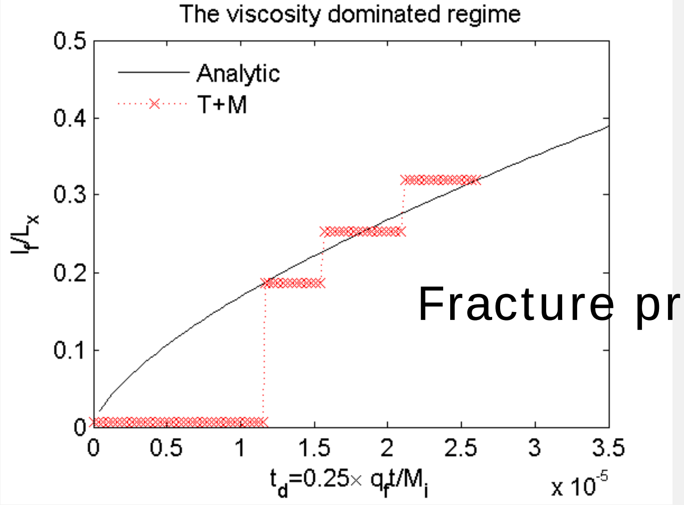
Code Verification (T+M)
2D Plane strain geomechanics



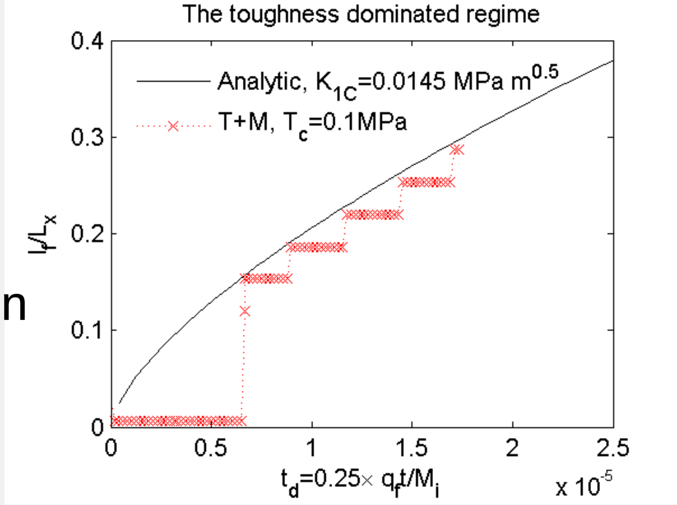
Poromechanical effects



Static fractures

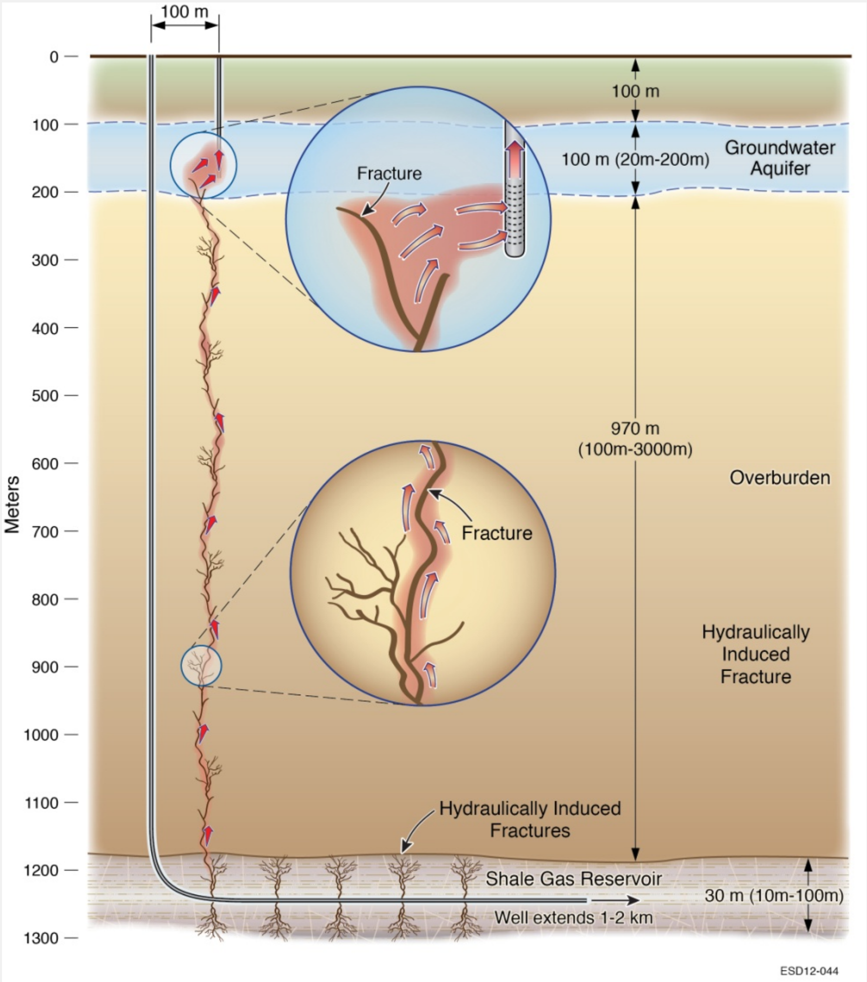


Fracture propagation

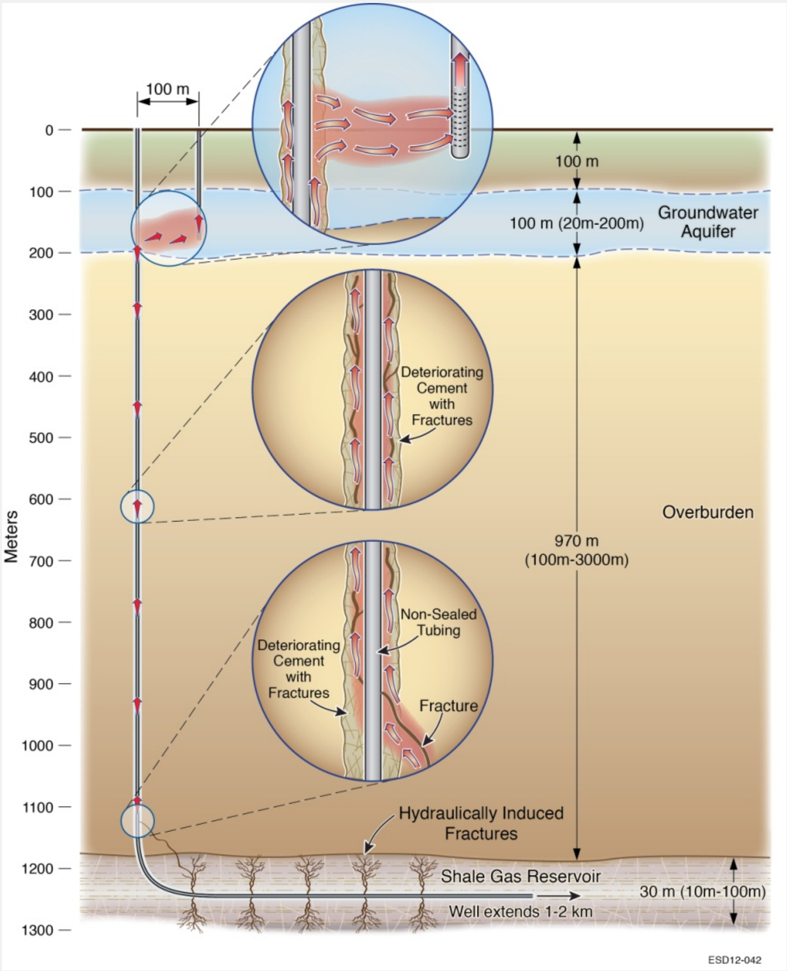


Numerical and analytical results are in good agreement.

Failure scenarios (?)

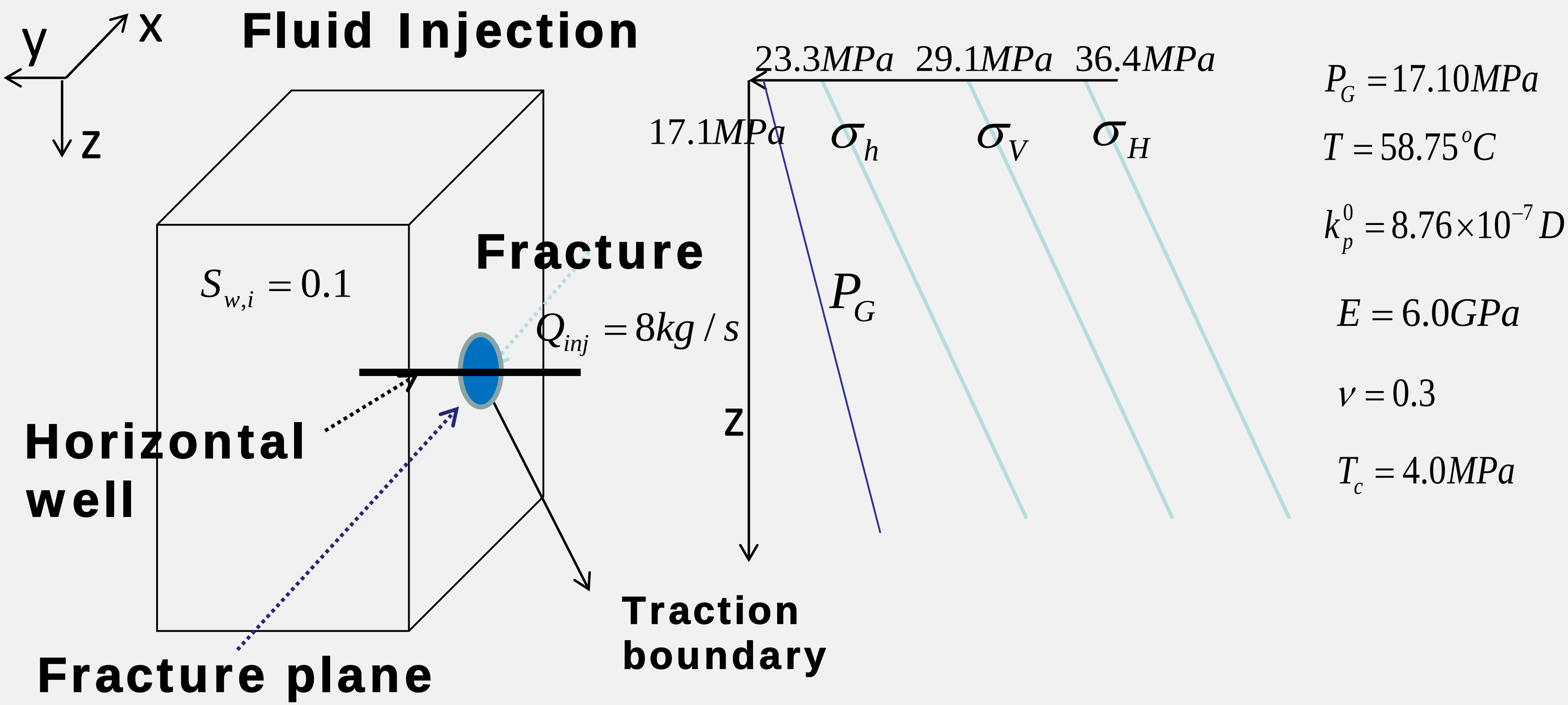


HF extending from shale to shallow aquifer through the overburden



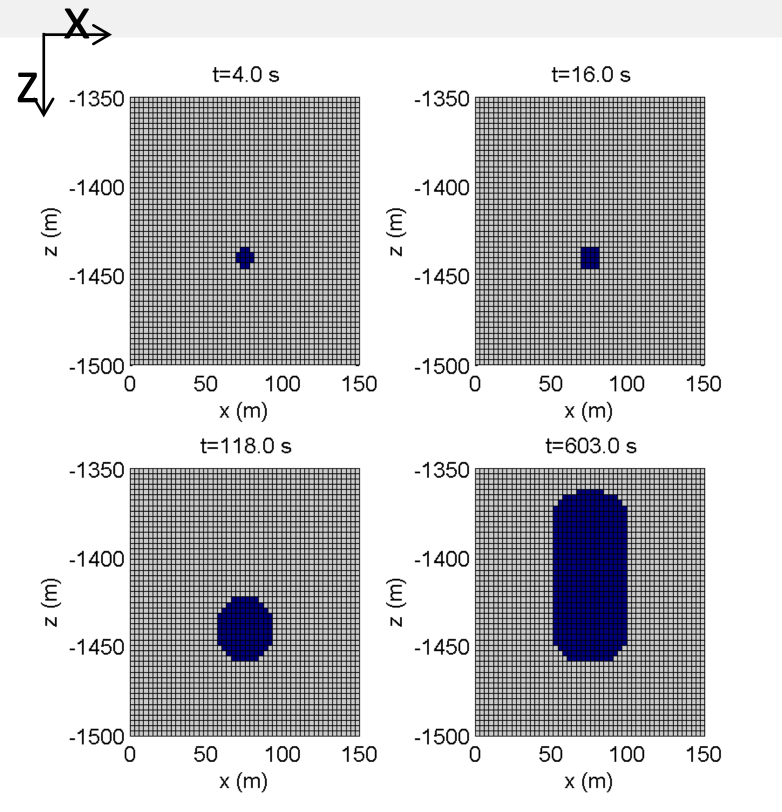
HF extending from shale to shallow aquifer through weak cement (not discussed today)

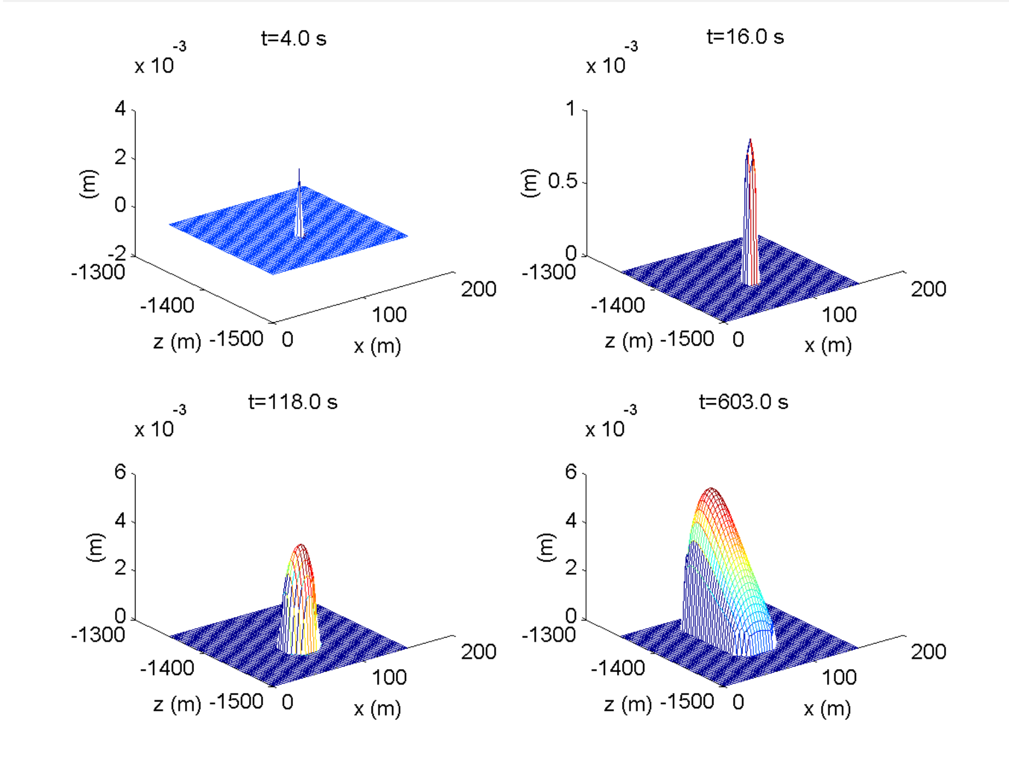
3D Domain



Investigate fracture propagation in shale gas reservoirs - **properties of Marcellus shale**

Fracture Propagation (I)





Fractured areas

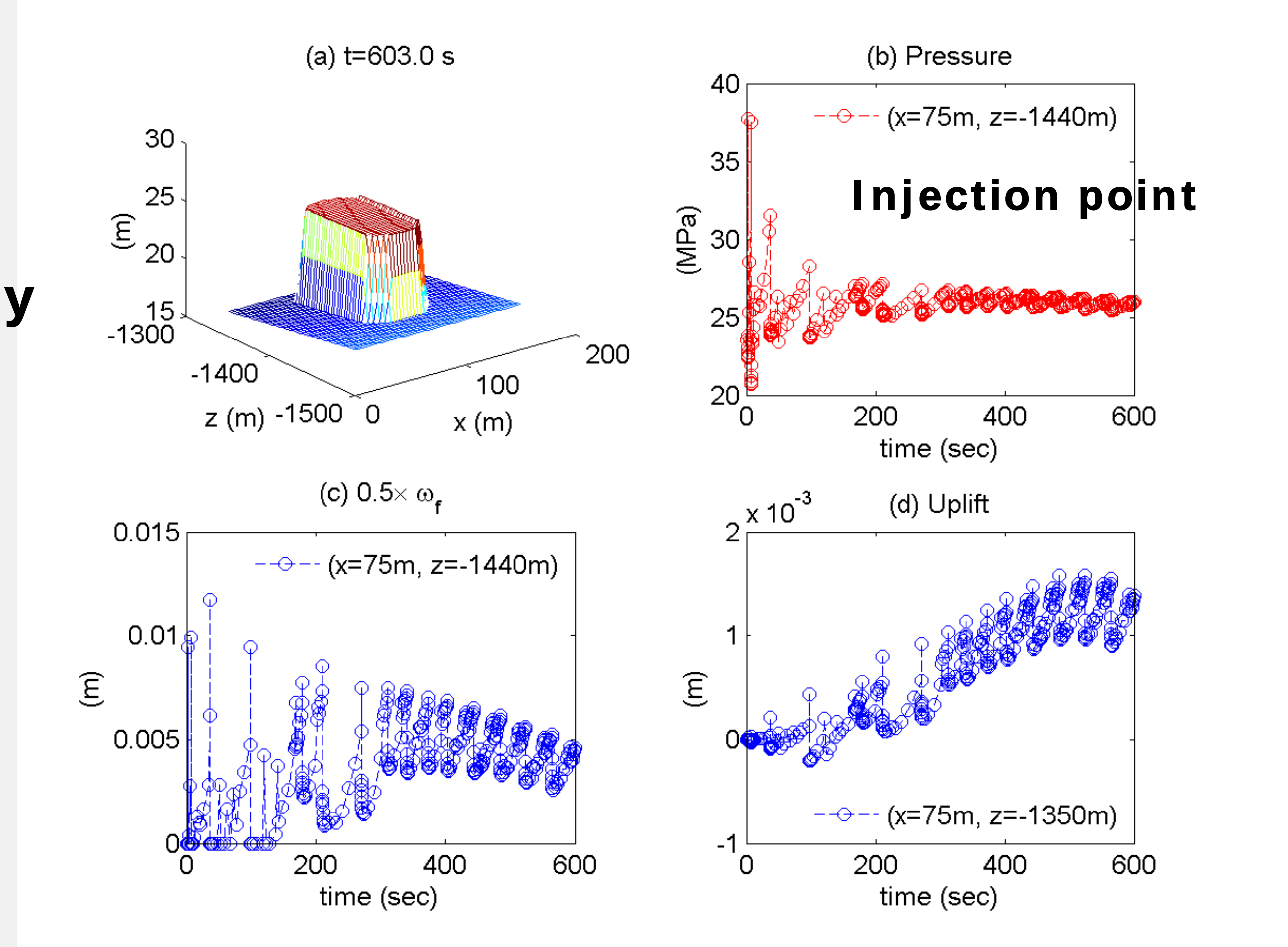
Fracture aperture

Example of fracture propagation

Larger fracture aperture near the fracture top

Fracture Propagation (II)

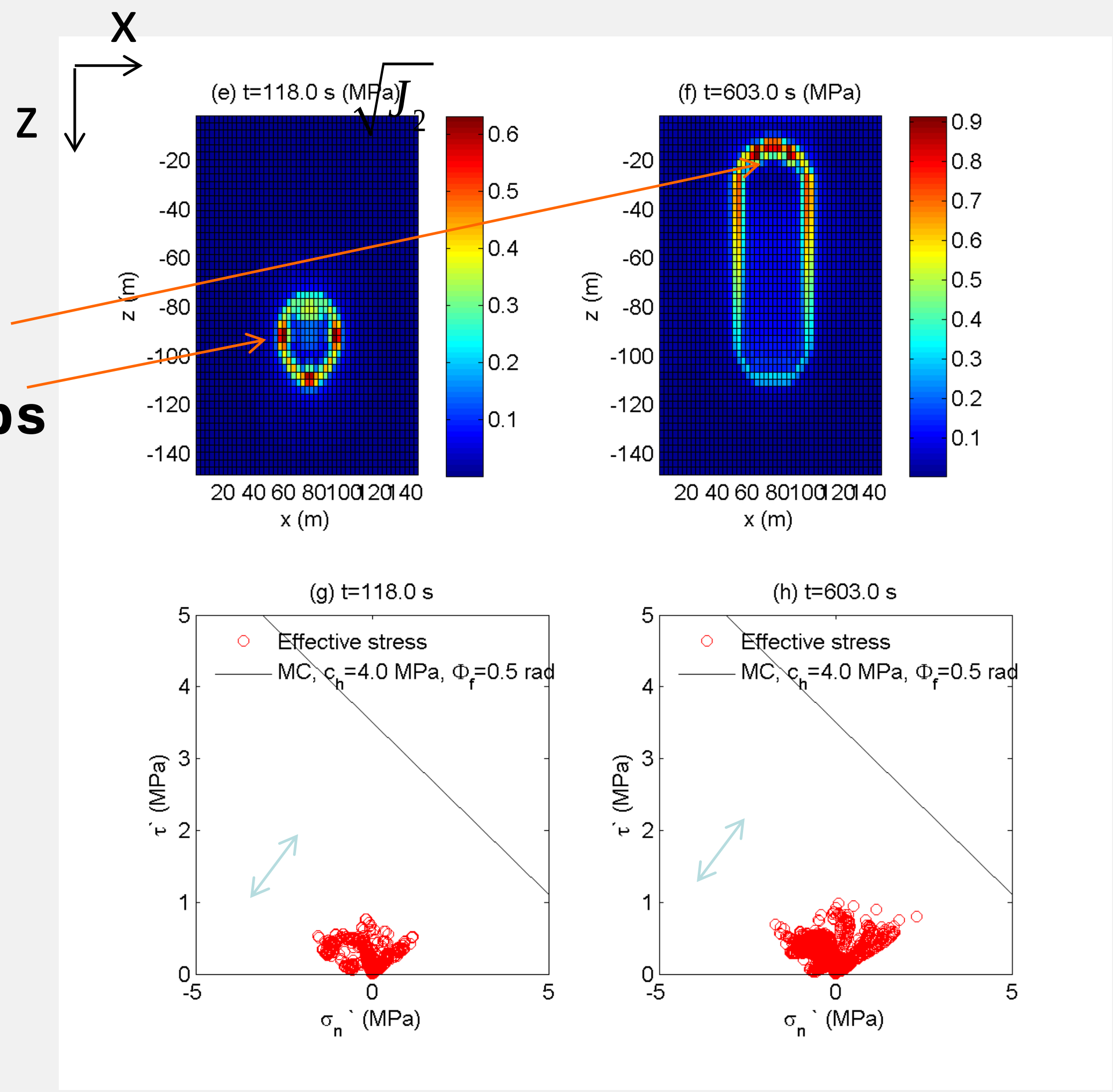
Fast pressure diffusion due to high permeability



Saw-tooth (oscillatory) pressure, fracture aperture, displacement

Can be considered as microearthquakes induced by tensile failure

Shear stress study: an example



High shear stress near the fracture tips

Investigating the probability of shear failure

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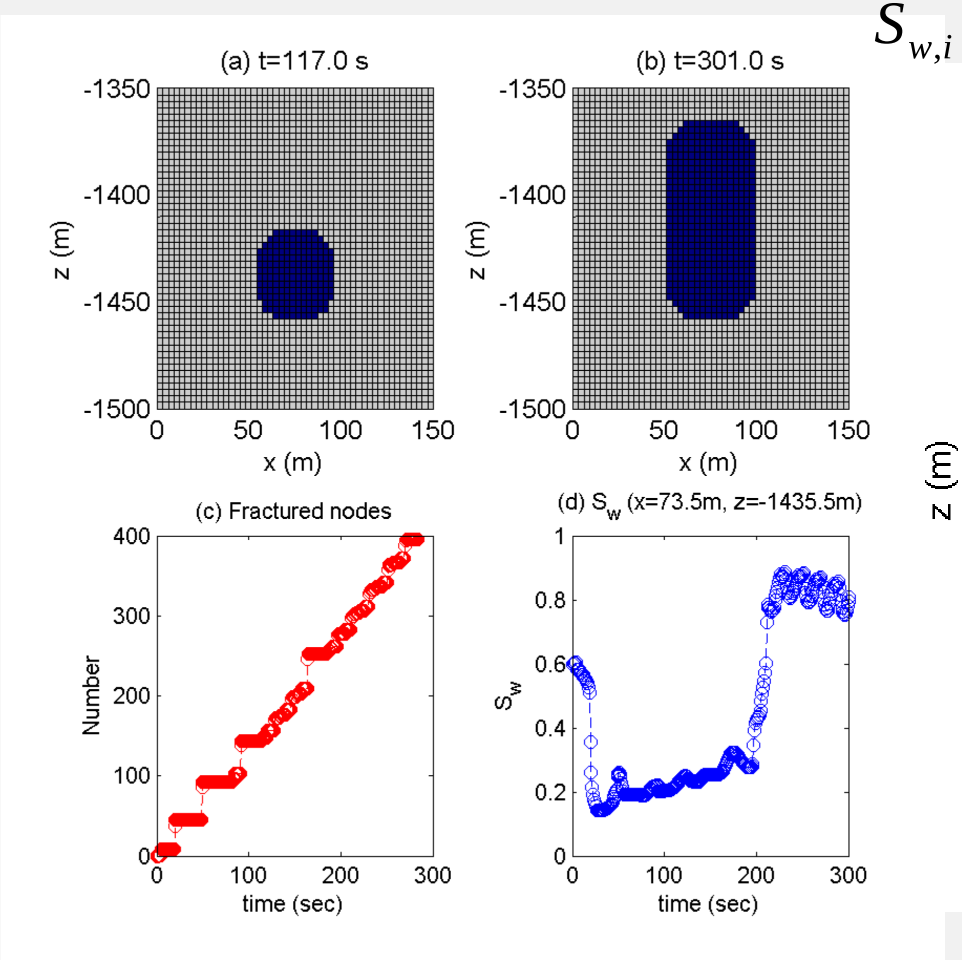
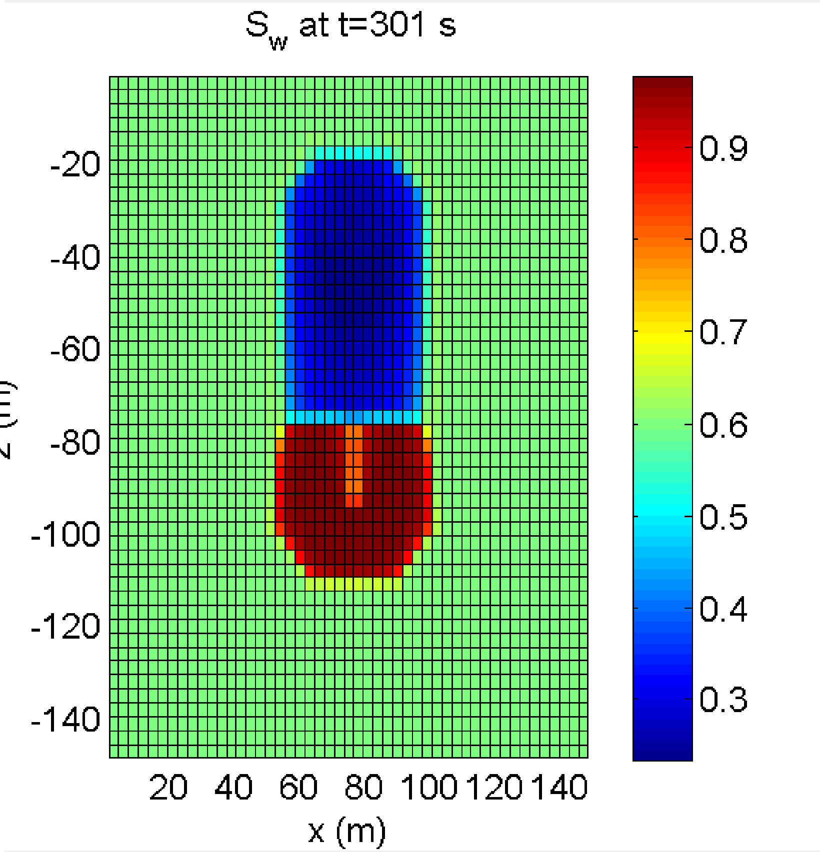
Coexistence of water & gas



$$S_{w,i} = 0.6$$

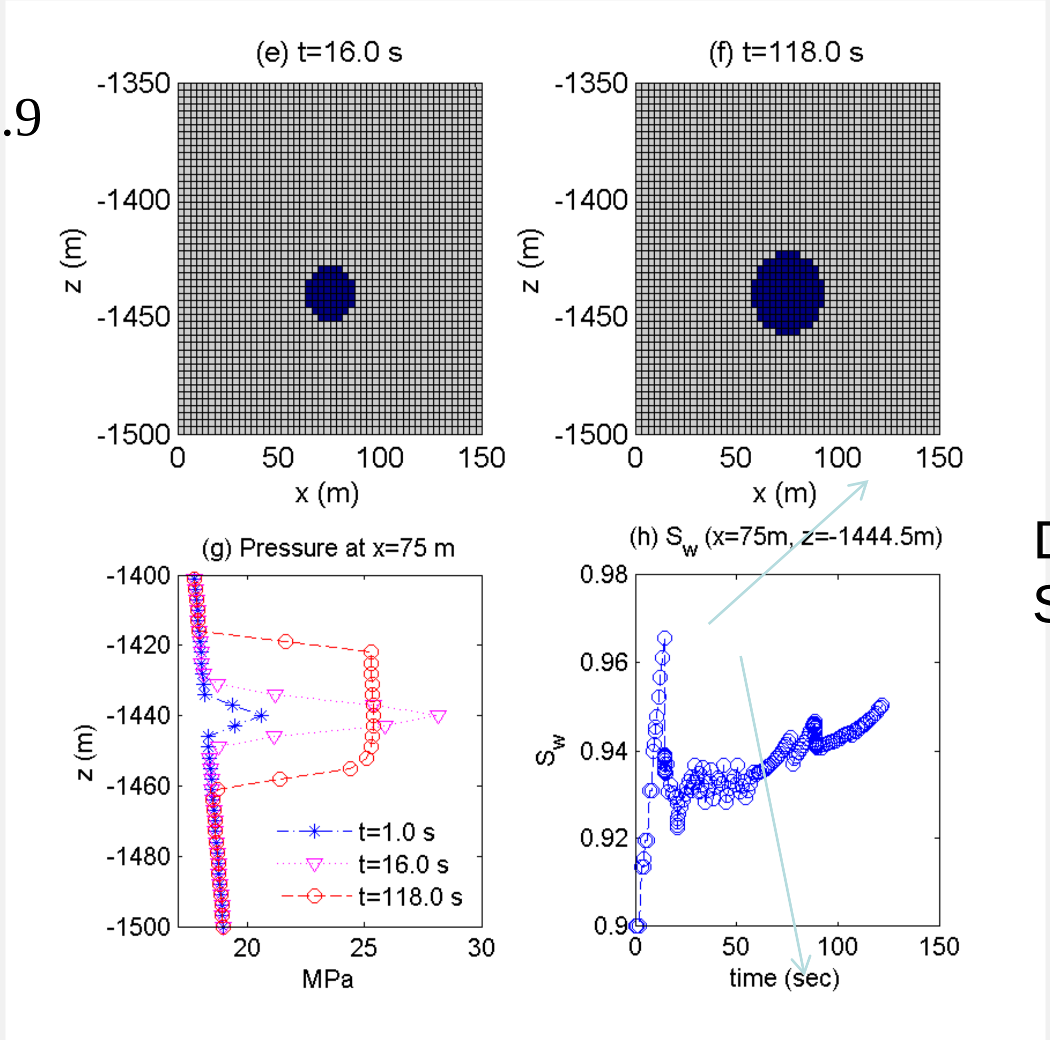


Simple calculation by only the injection volume might significantly underestimate the fracture volume and propagation.

Complex multiphase flow with gravity segregation within the fracture

Water injection: fundamental issues

$$S_{w,i} = 0.9$$



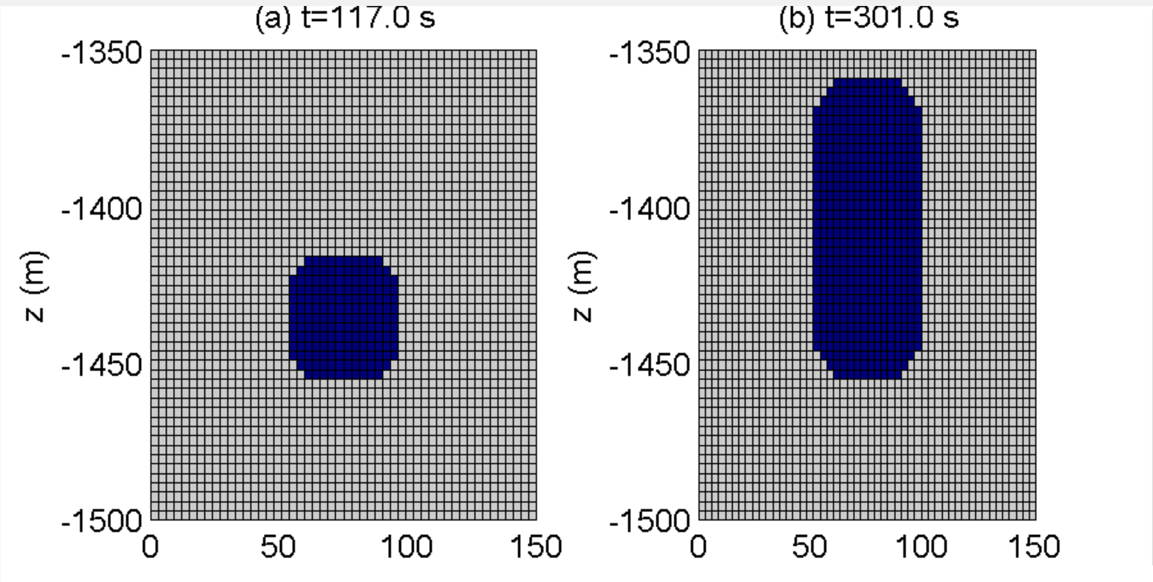
Does not approach Sw = 1.0

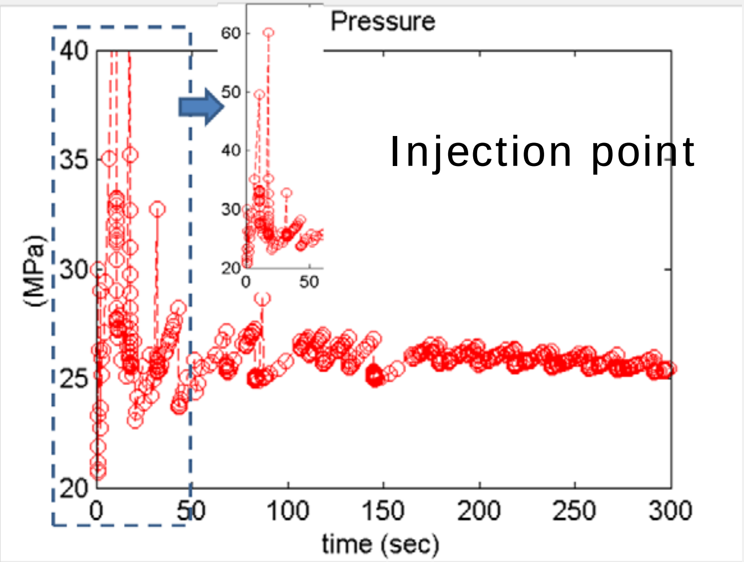
Water & gas still coexist within the fracture.
Water saturation drops at the time when fracturing occurs.

Higher Injection Rate

$$Q_{inj} = 16 kg/s$$

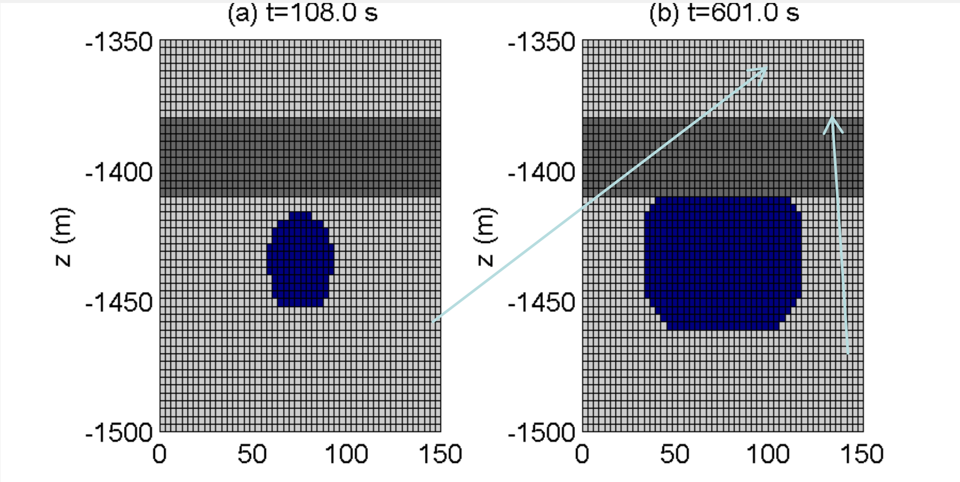
Higher peak pressure



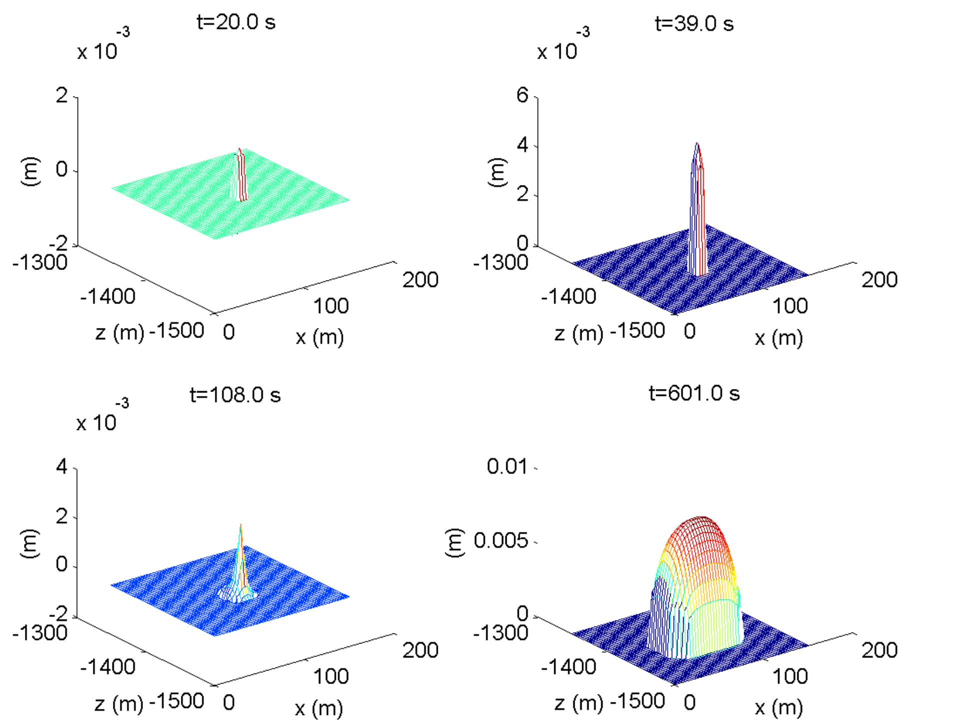


Higher injection rate = faster fracture propagation

Heterogeneity effects



A strong geological formation with τ_c = 10 MPa



A strong geological formation can block vertical fracture propagation

Conclusions

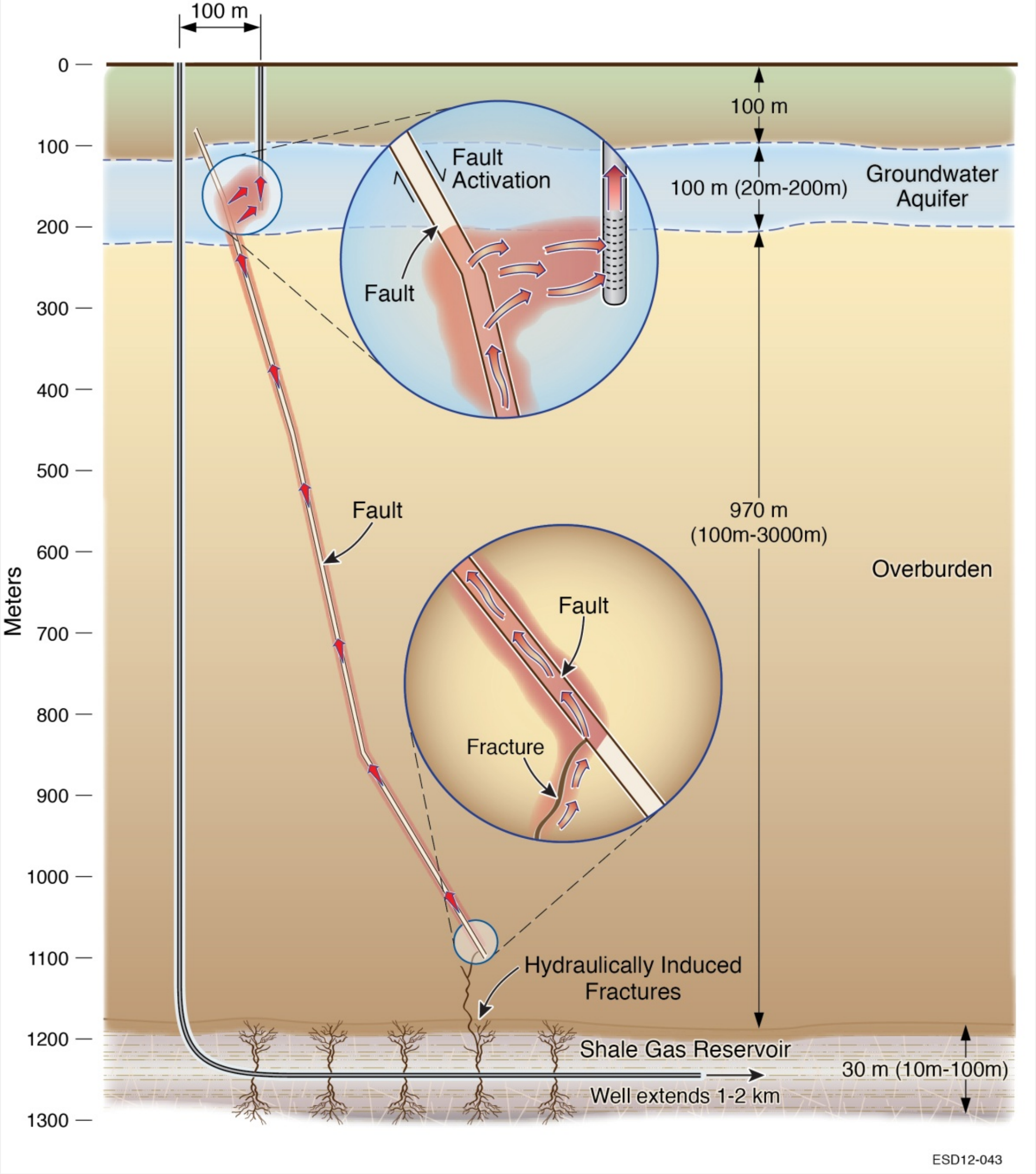
- Developed a hydraulic fracturing simulator
- Investigated fracture propagation scenarios in Marcellus shales
- Identifying the factors controlling fracture propagation
- Estimation based on the injection volume may significantly underestimate the fracture volume & its propagation

Rigorous modeling of fracture propagation & accurate geophysical monitoring are strongly recommended

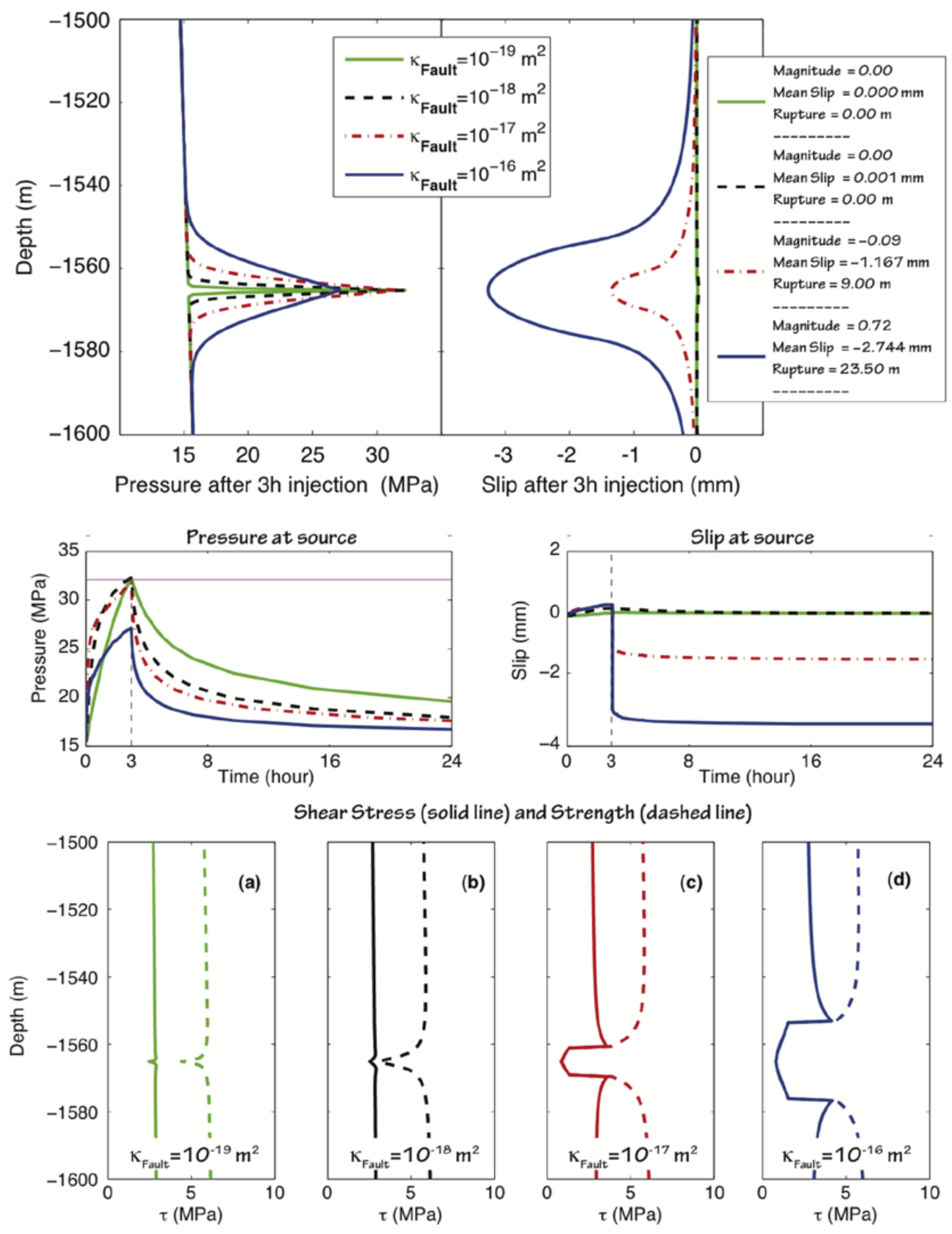
Failure scenarios (?)

Fault activation during the hydraulic fracturing process

Code:
TOUGH+ RealGasH2O+ FLAC3d



Constant rate of P-increase



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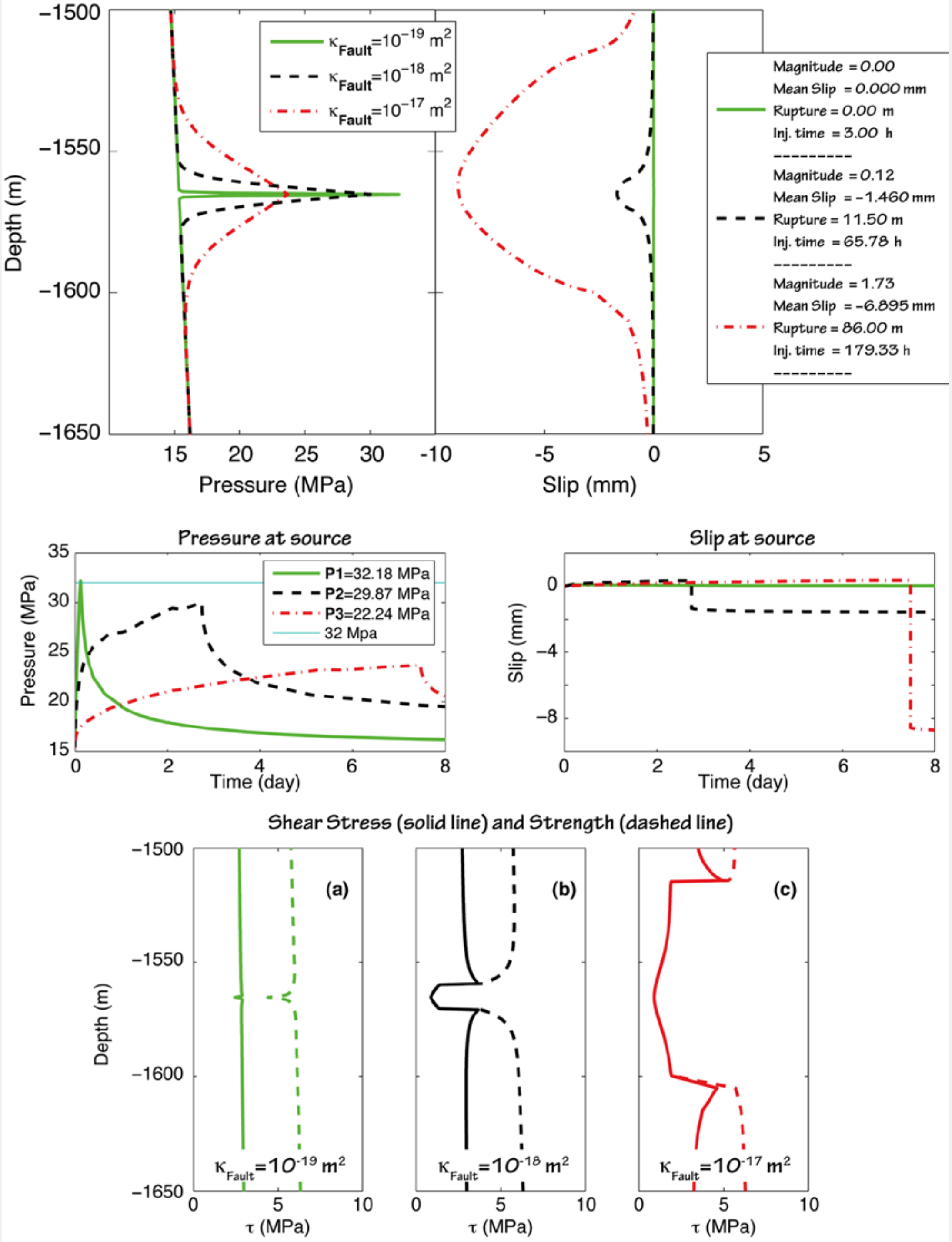
Constant rate of injection



Acknowledgements

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Thank you