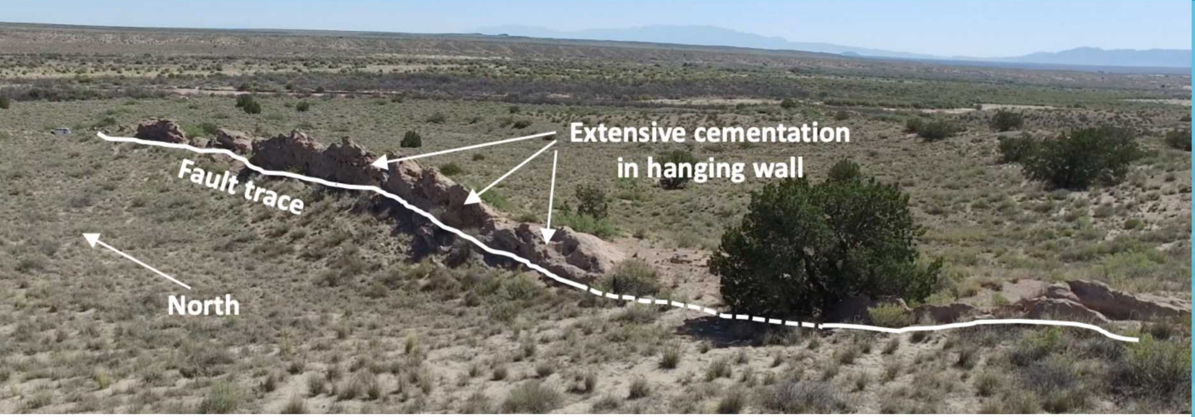
SAND2020-8160PE

Multiphysics-driven geomechanical instability: Implications for subsurface energy activities



PRESENTED BY

Kyung Won (K-Won) Chang

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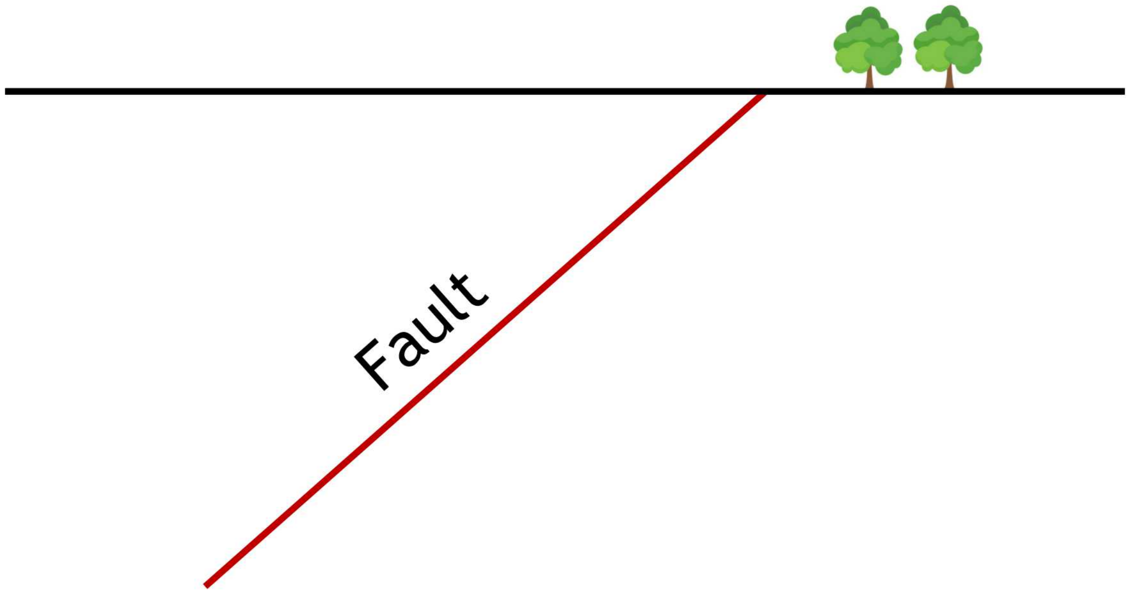
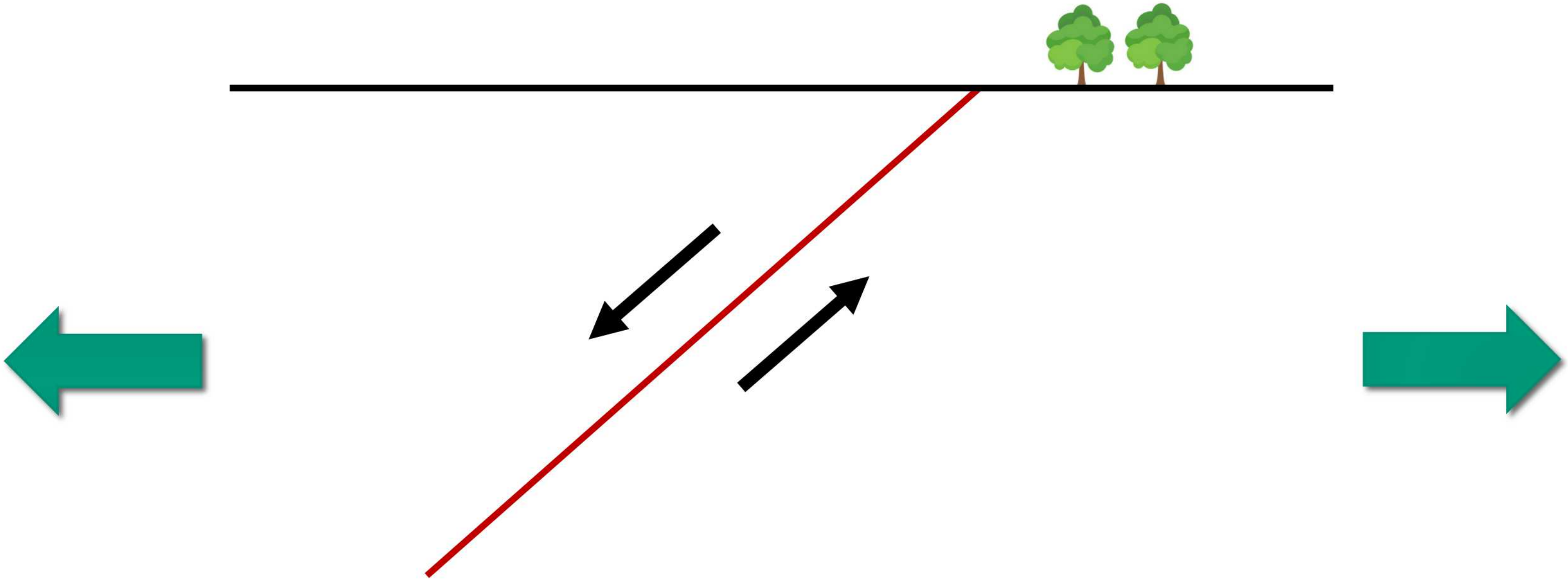
Geomechanical failure mechanisms



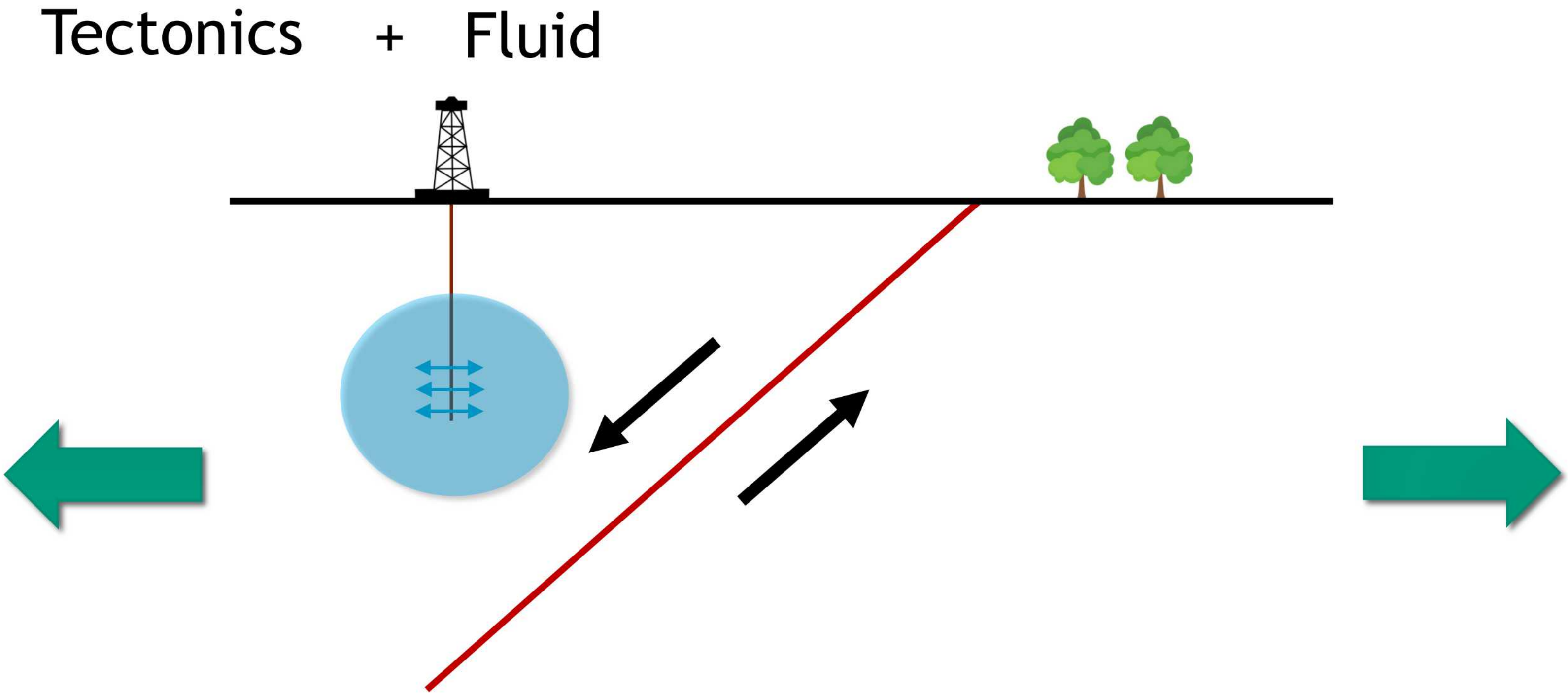
Geomechanical failure mechanisms

Tectonics



Δ(In-situ stress)

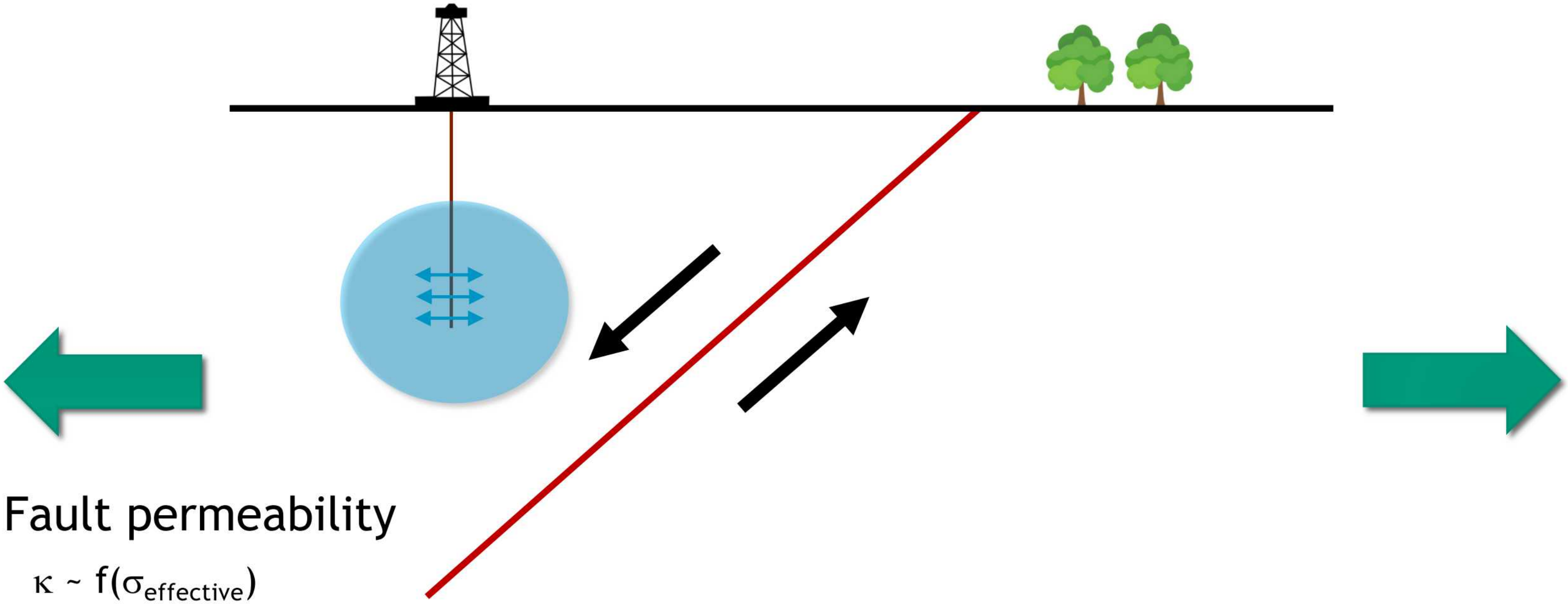
Geomechanical failure mechanisms



Δ(In-situ stress) + Δ(p, T, c)

Geomechanical failure mechanisms

Tectonics + Fluid + Dynamics



- Fault permeability

  $\kappa \sim f(\sigma_{effective})$

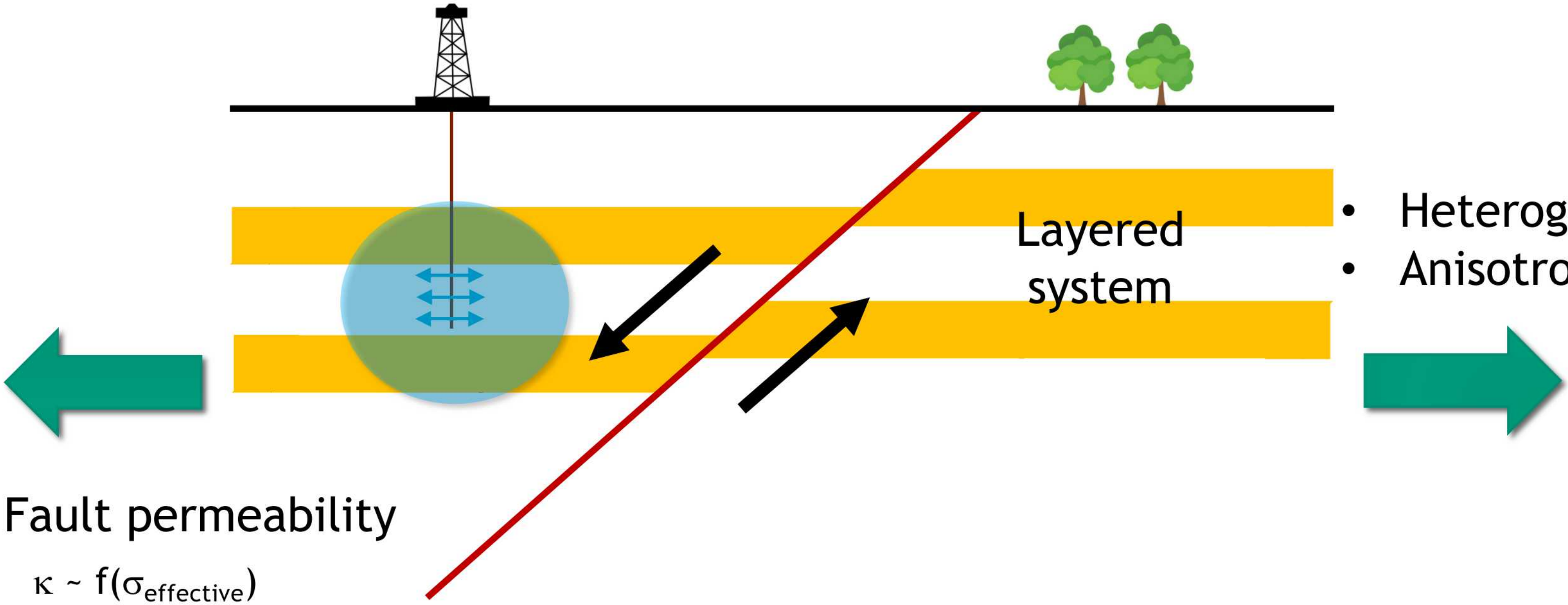
- Frictional properties

  Rate and state friction

Δ(In-situ stress) $+ \Delta$(p, T, c) $+ \Delta$(Material characteristics)

Geomechanical failure mechanisms

Tectonics + Fluid + Dynamics + Architecture



- Heterogeneity
- Anisotropy

- Fault permeability

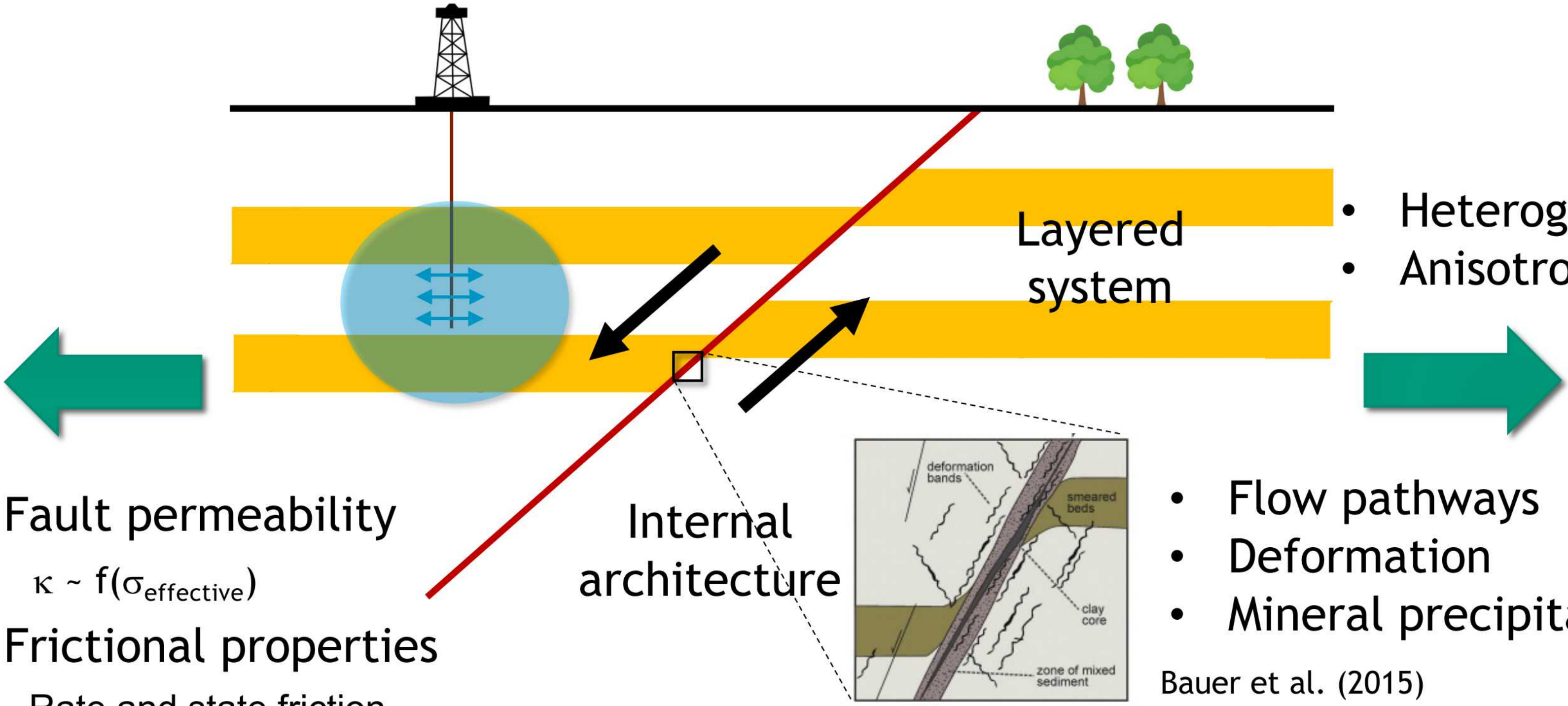
  $\kappa \sim f(\sigma_{\text{effective}})$
- Frictional properties

  Rate and state friction

$$\Delta(\text{In-situ stress}) + \Delta(p, T, c) + \Delta(\text{Material characteristics})$$

Geomechanical failure mechanisms

Tectonics + Fluid + Dynamics + Architecture



Layered system

- Heterogeneity
- Anisotropy

Internal architecture

- Flow pathways
- Deformation
- Mineral precipitation

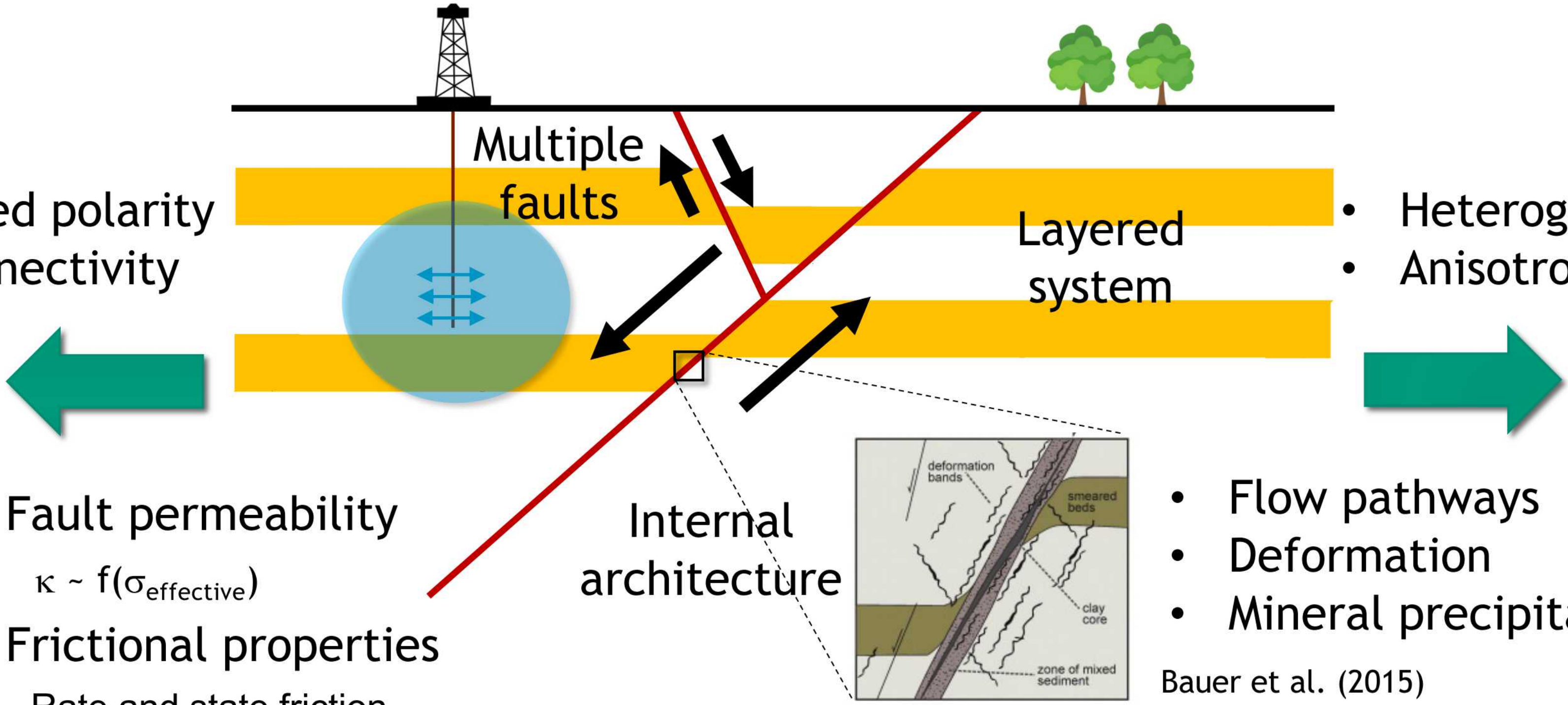
Bauer et al. (2015)

- Fault permeability
  $\kappa \sim f(\sigma_{effective})$
- Frictional properties
  Rate and state friction

Δ(In-situ stress) + Δ(p, T, c) + Δ(Material characteristics)

Geomechanical failure mechanisms

Tectonics + Fluid + Dynamics + Architecture



Multiple faults

Layered system

Internal architecture

- Mixed polarity
- Connectivity

- Heterogeneity
- Anisotropy

- Fault permeability

  $\kappa \sim f(\sigma_{effective})$
- Frictional properties

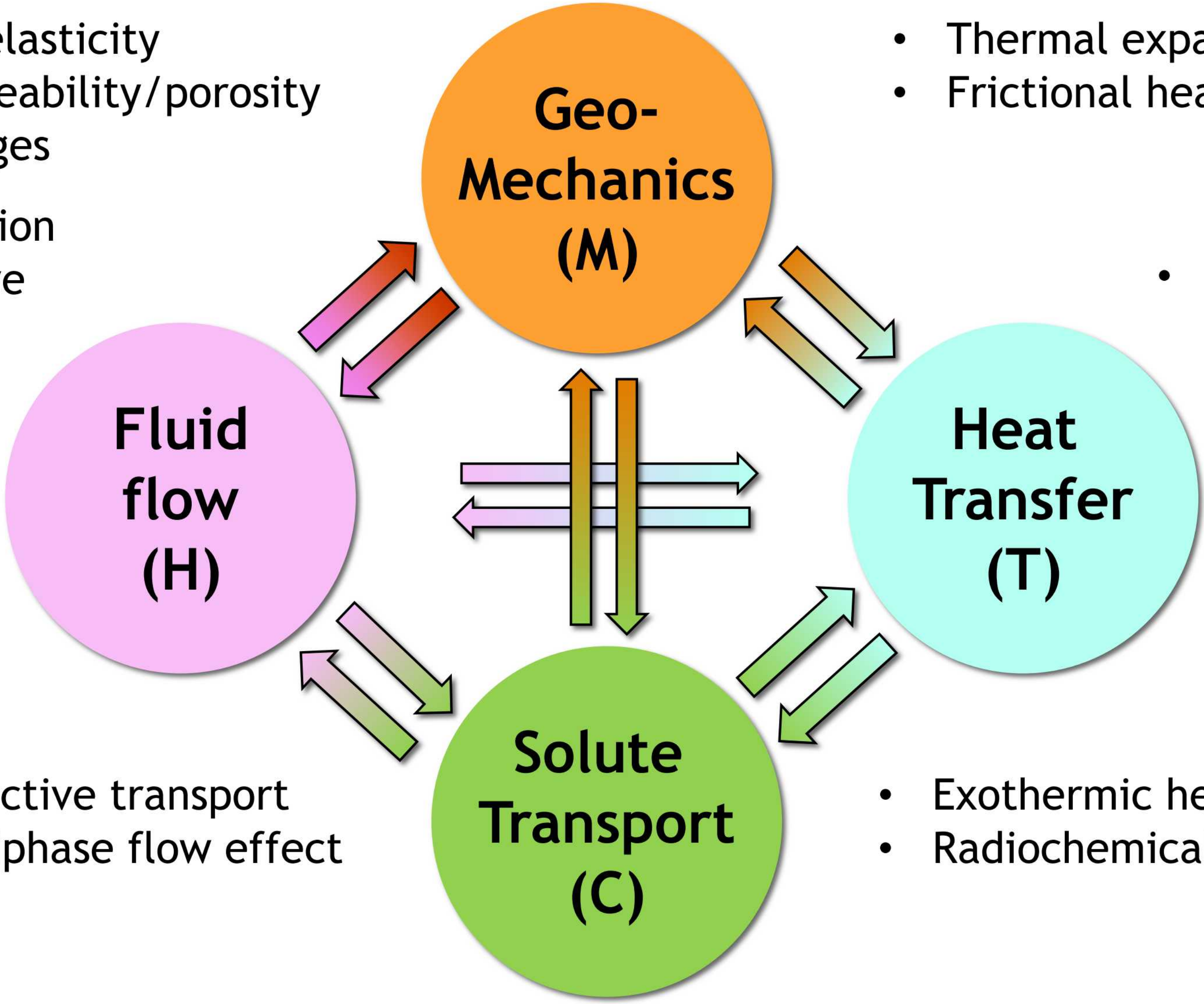
  Rate and state friction

- Flow pathways
- Deformation
- Mineral precipitation

Bauer et al. (2015)

Δ(In-situ stress) + Δ(p, T, c) + Δ(Material characteristics)

Multiphysics in rock-fluid interaction



- Poroelasticity
- Permeability/porosity changes

Geo-Mechanics (M)

- Thermal expansion
- Frictional heating

- Deformation of reactive surface

- Convective heat transport

Fluid flow (H)

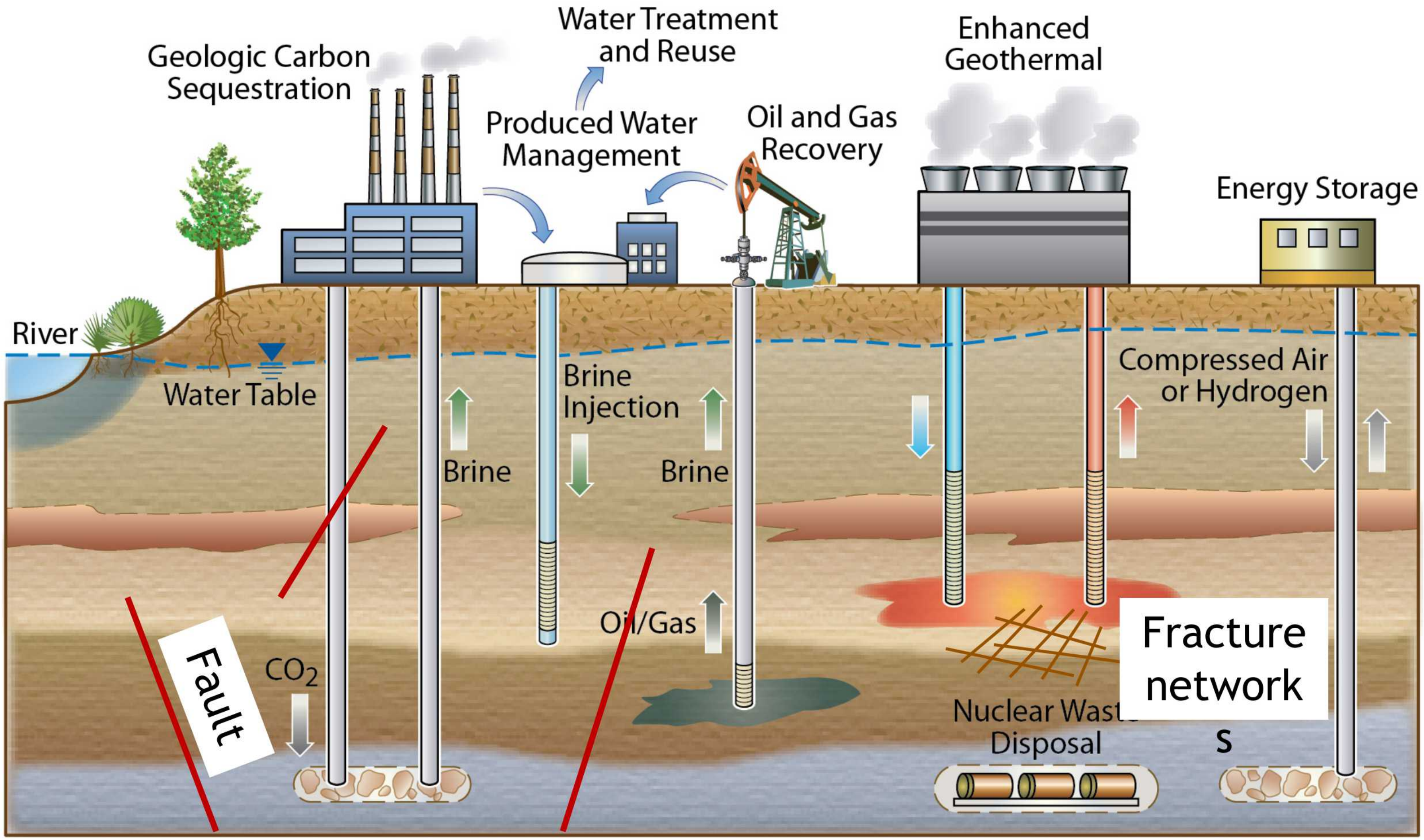
Heat Transfer (T)

Solute Transport (C)

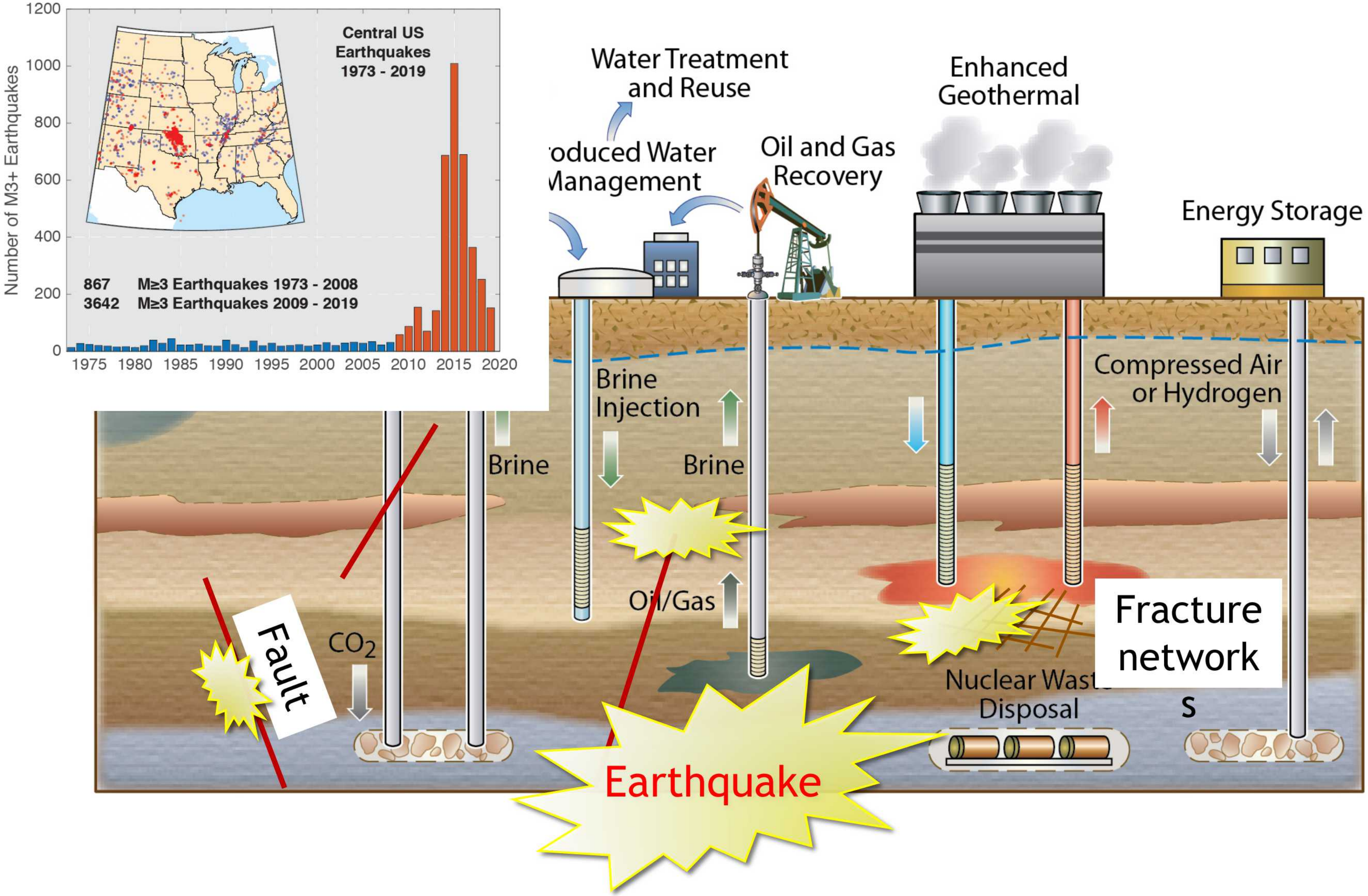
- Advective transport
- Multiphase flow effect

- Exothermic heat
- Radiochemical reaction

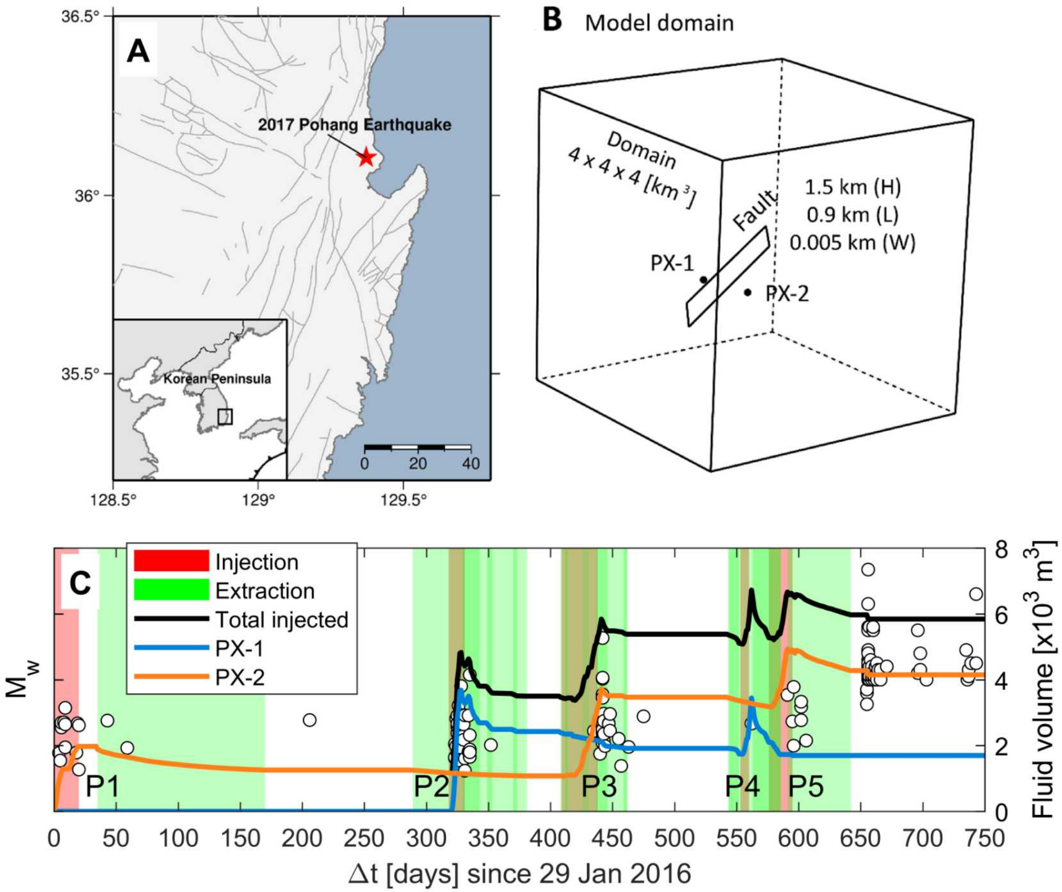
Subsurface energy activities



Potential risk 1. Induced Earthquake



Case study: 2016-2017 Pohang EQs



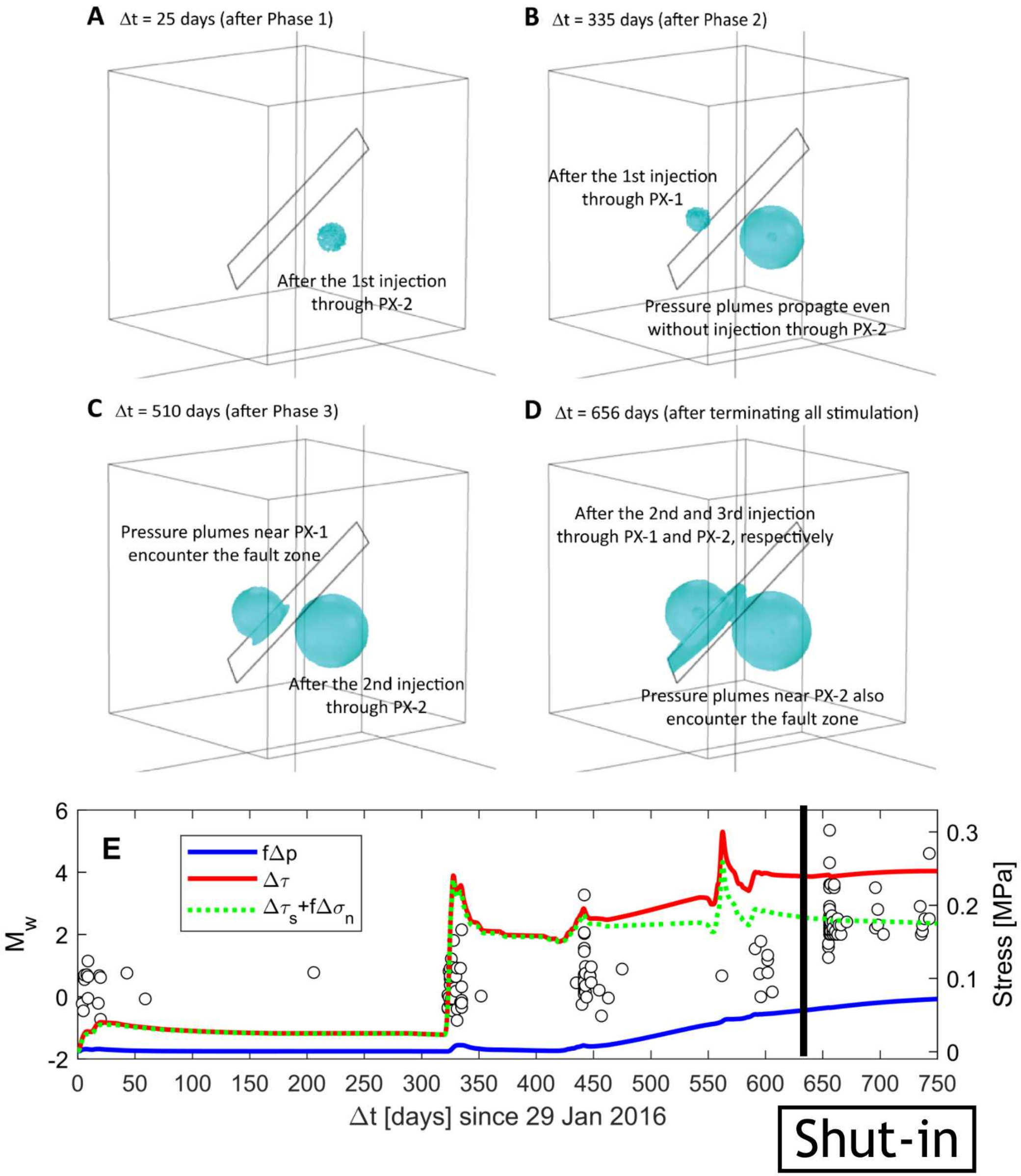
- Poroelastic coupling effects on induced earthquakes quantified by Coulomb stress change

$$\Delta\tau = \underbrace{(\Delta\tau_s + f\Delta\sigma_n)}_{\text{Poroelastic stress}} + \underbrace{f\Delta p}_{\text{Pore pressure}}$$

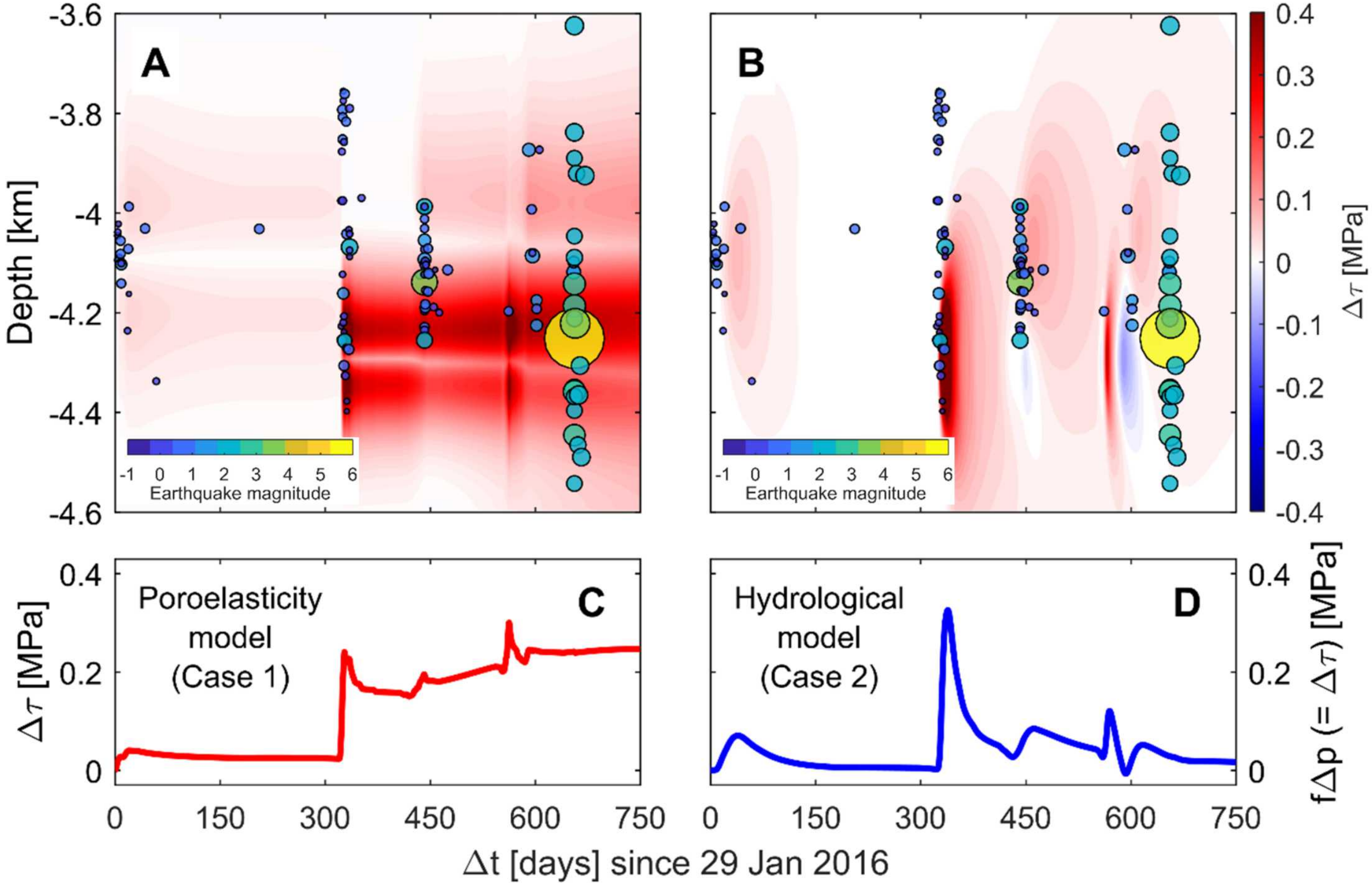
- Under the uncoupled system,

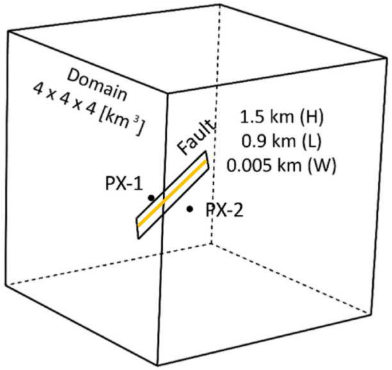
$$\Delta\tau = f\Delta p$$

TH Model


A Δt = 25 days (after Phase 1)
After the 1st injection through PX-2
B Δt = 335 days (after Phase 2)
After the 1st injection through PX-1
Pressure plumes propagte even without injection through PX-2
C Δt = 510 days (after Phase 3)
Pressure plumes near PX-1 encounter the fault zone
After the 2nd injection through PX-2
D Δt = 656 days (after terminating all stimulation)
After the 2nd and 3rd injection through PX-1 and PX-2, respectively
Pressure plumes near PX-2 also encounter the fault zone
E
fΔp
Δτ
Δτ_s+fΔσ_n
M_w
6
4
2
0
-2
Stress [MPa]
0.3
0.2
0.1
0
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
Δt [days] since 29 Jan 2016
Shut-in

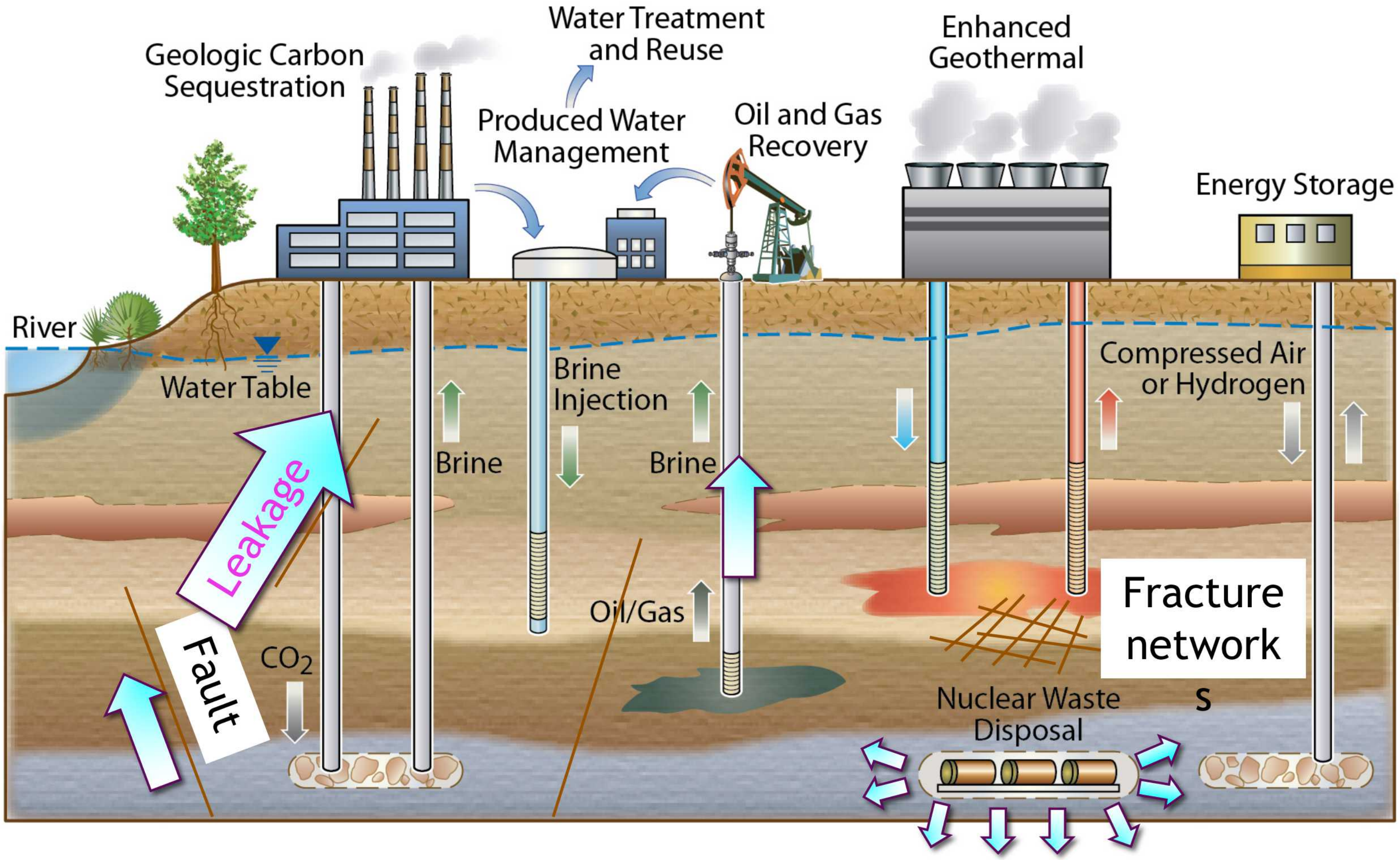
Coupled vs. uncoupled models





Chang *et al.* (2020) *Sci. Rep.*

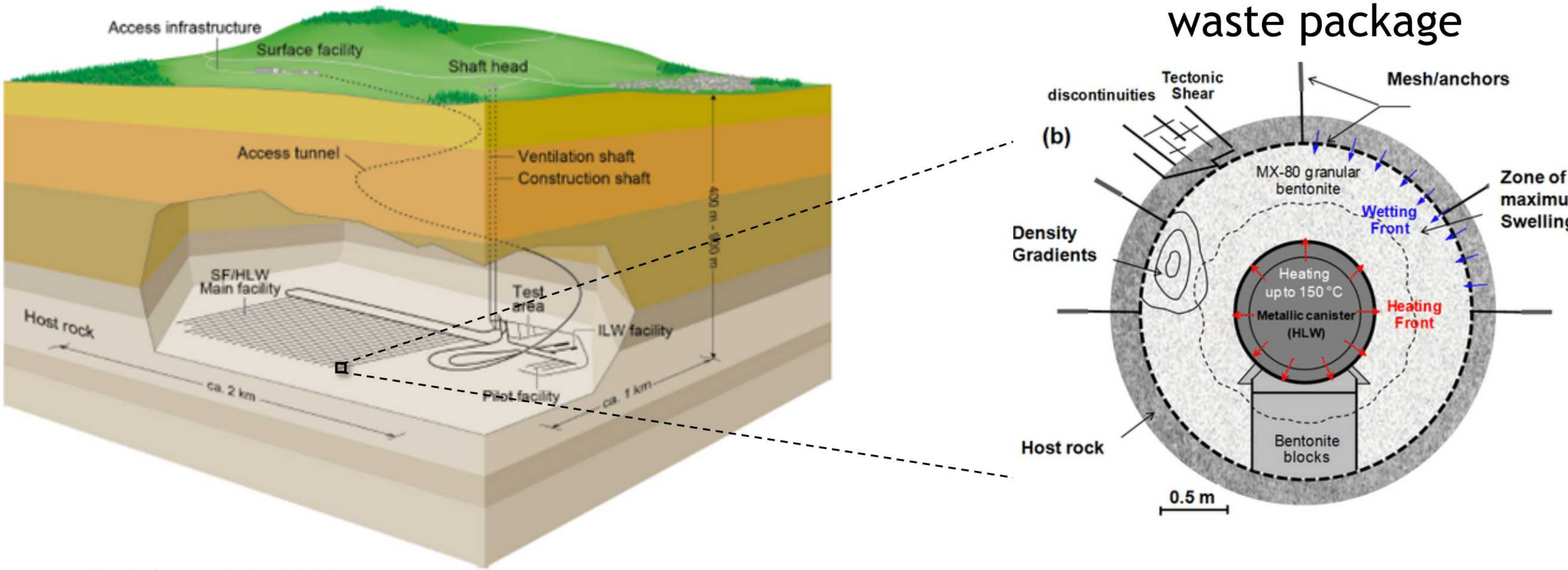
Potential risk 2. Leakage



Nuclear waste disposal

Field-scale modeling of entire nuclear waste repository

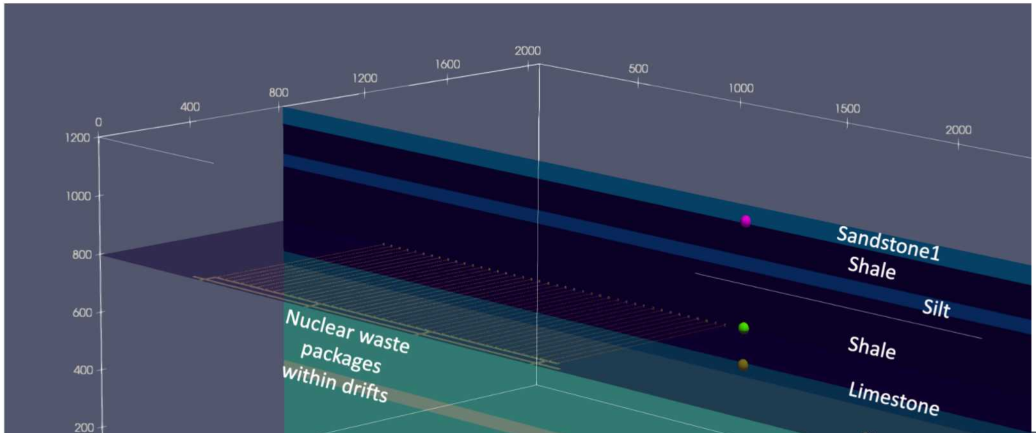
Near-field rock-fluid interaction around a single waste package



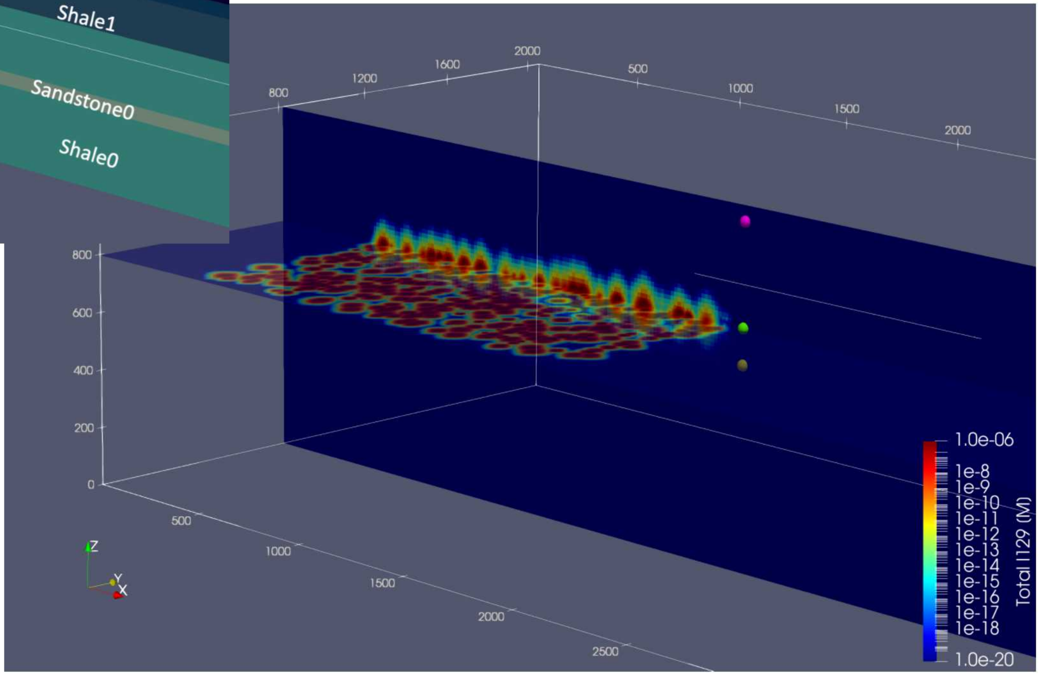
Seiphoori (2015)

- Field-scale simulations aims for safe disposal more than 10^6 years
- Near-field physical and chemical behaviors of local flows and transports driven by multiphysics coupling processes

Field-scale THC model

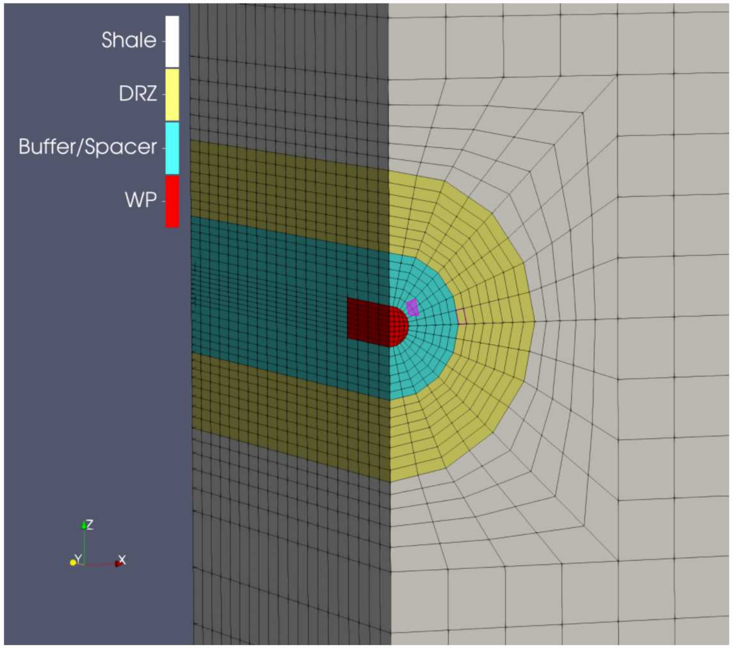


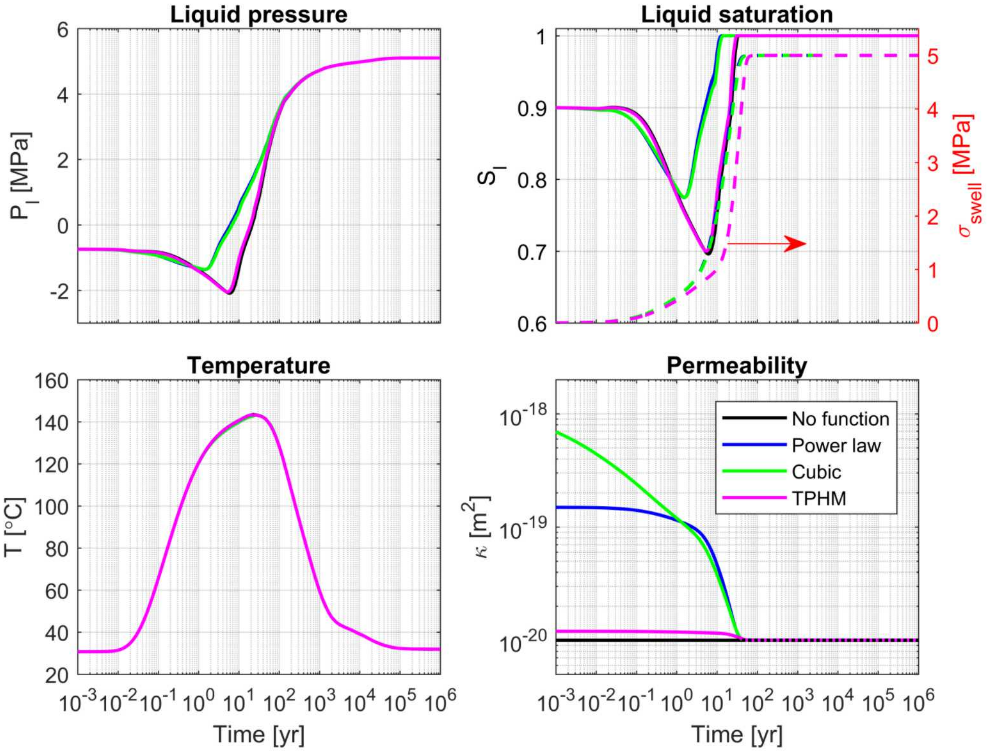
- 2575 nuclear waste packages are emplaced in a layered shale system
- 7km(L) x 2km(W) x 1.2km(H)



- Multiphysics-driven rock-fluid interactions determine transport of radio-nucleoids
- ^{129}I (Iodine) distribution after 10^4 years due to breach of waste packages

Near-field THMC mechanism





- As DRZ heated, precipitation occurs (decrease in S_l) at early time.
- During re-saturation, swelling buffer exerts normal stresses to compact fractures in DRZ which reduces DRZ permeability

$$\Delta\sigma_{swelling} = 3K\Delta S_l\beta_{sw} = \Delta\sigma_{eff} \longrightarrow \kappa \sim f(\Delta\sigma_{eff})$$

- To see how THM process affects geochemical transport of radio-nucleoids and ultimately support site selection as well as construction plans

Question & Answer

Chang, K.W. and H. Yoon (2018), 3-D modeling of induced seismicity along multiple faults: Magnitude, rate, and location in a poroelasticity system, *JGR Solid Earth*, 123(11):9866-9883.

Chang, K.W., H. Yoon, Y.-H. Kim, M.Y. Lee (2020), Operational and geological controls of coupled poroelastic stressing and pore-pressure accumulation along faults: Induced earthquakes in Pohang, South Korea, *Scientific Reports*, 10:2073.

Sevougian, S.D., E. Stein, T. LaForce, F. Perry, T.S. Lowry, L.J. Cunningham, M. Nole, C.B. Haukwa, **K.W. Chang**, P. Mariner (2019), GDSA Repository Systems Analysis Progress Report, No. SAND2019-5189R. Sandia National Lab.(SNL-NM), Albuquerque, NM (United States)

Sevougian, S.D., E. Stein, T. LaForce, F. Perry, M. Nole, **K.W. Chang** (2019), GDSA Repository Systems Analysis FY19 Update, No. SAND2019-11942R. Sandia National Lab.(SNL-NM), Albuquerque, NM (United States)