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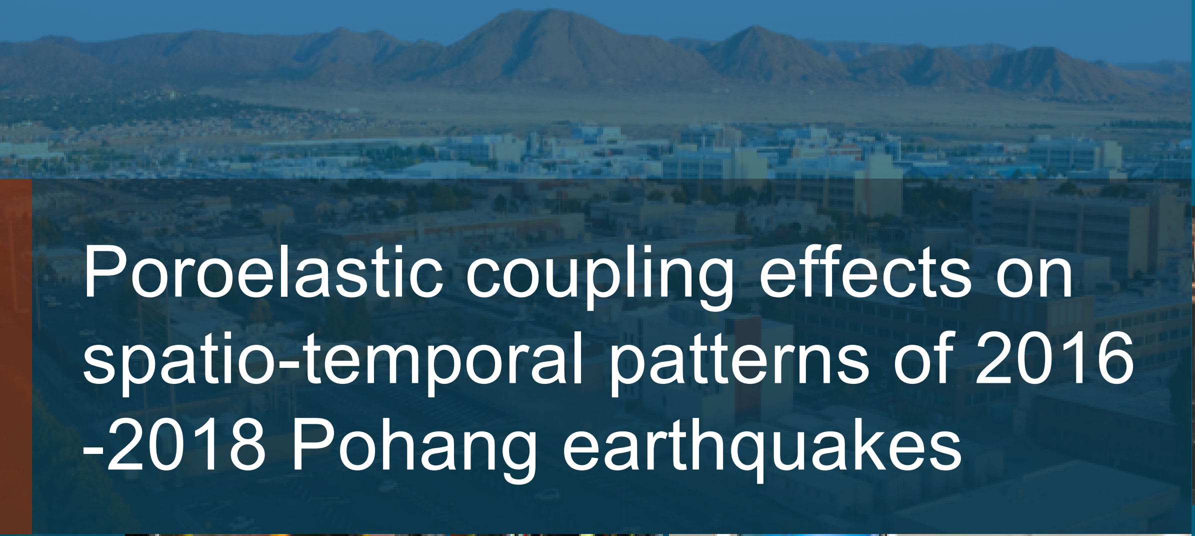


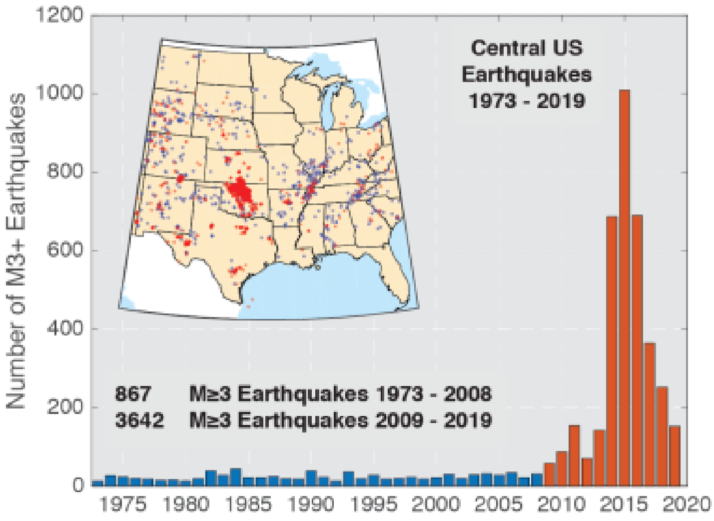
Poroelastic coupling effects on spatio-temporal patterns of 2016 -2018 Pohang earthquakes

SAND2020-

PRESENTED BY

Kyung Won (K-Won) Chang

Can Multiphysics Processes Explain the Mechanism Inducing Earthquakes?

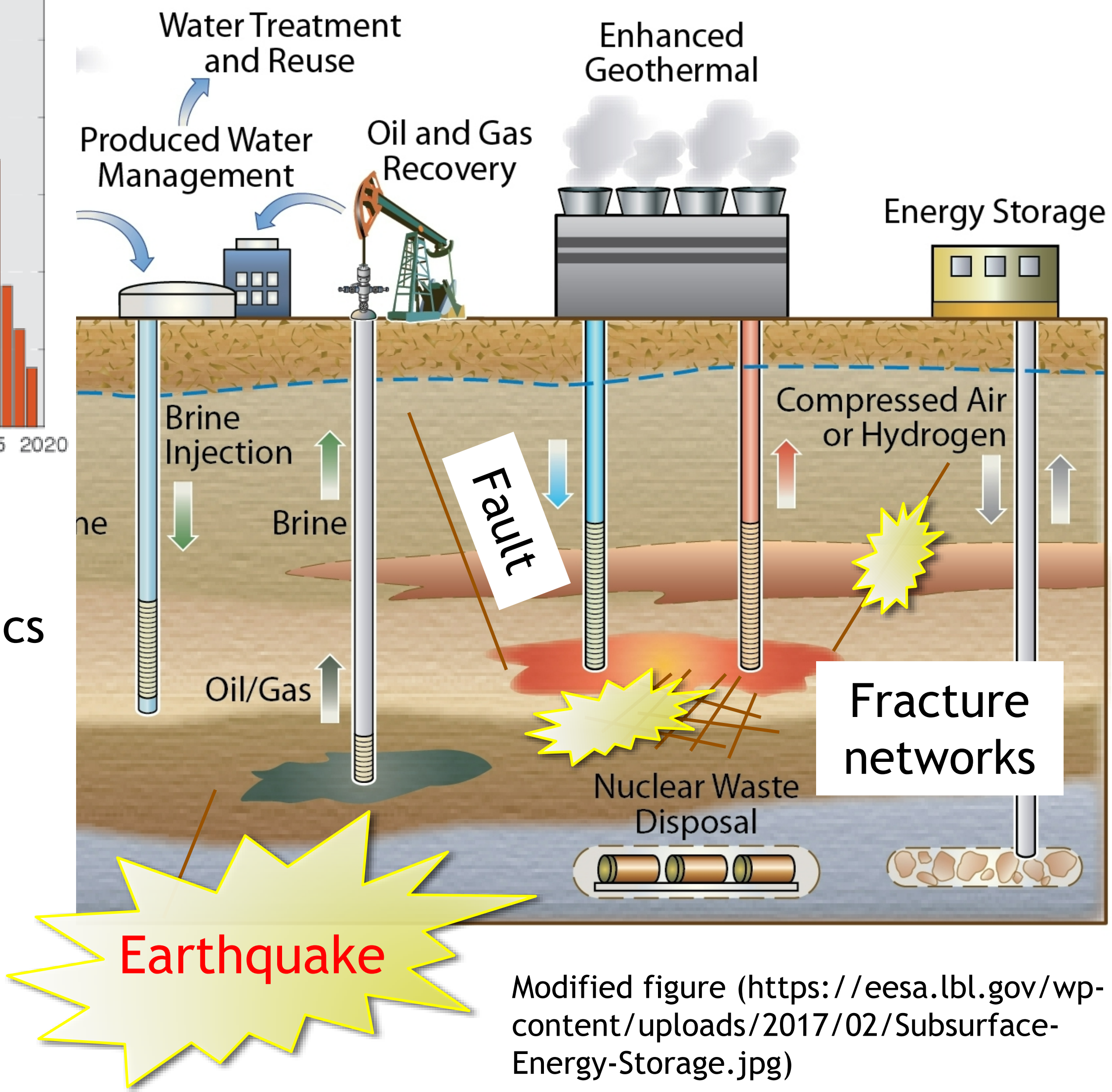


- Site-specific features

: Fault/fracture characteristics
  - Material properties
  - Geometry/orientation

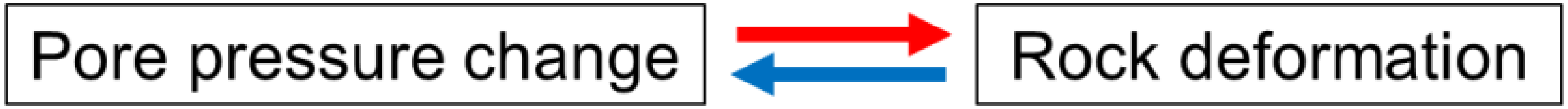
: Formation rock properties
  - Heterogeneity
  - Anisotropy

: Regional stress states



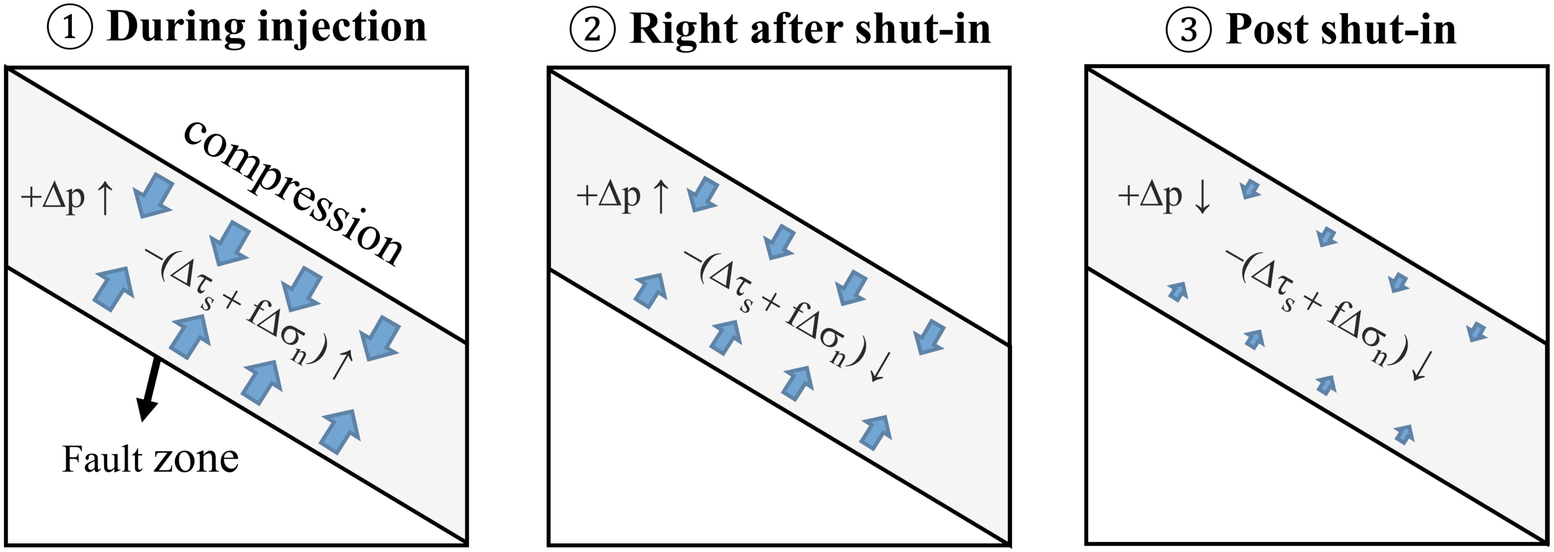
Modified figure (https://eesa.lbl.gov/wp-content/uploads/2017/02/Subsurface-Energy-Storage.jpg)

Poroelastic coupling within a fault zone



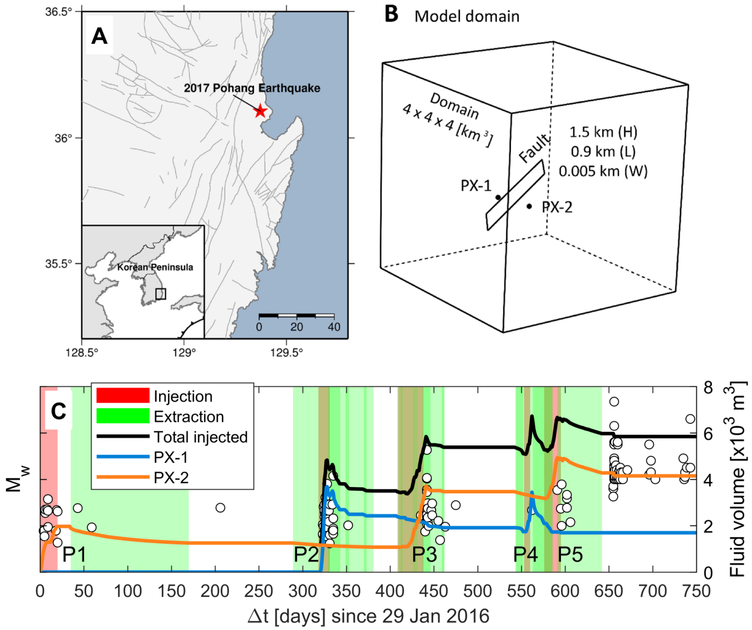
Pore pressure change

Rock deformation



Chang et al. (2018) BSSA.

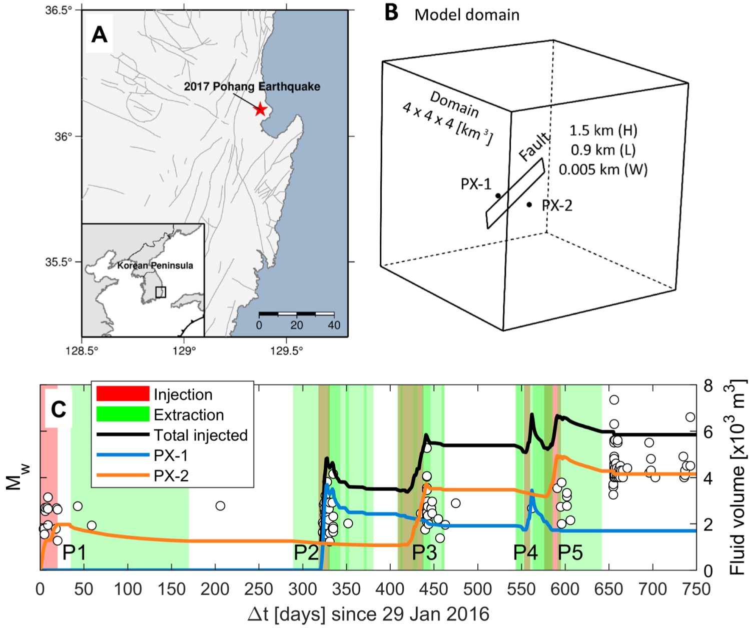
Application: 2016-2018 Pohang

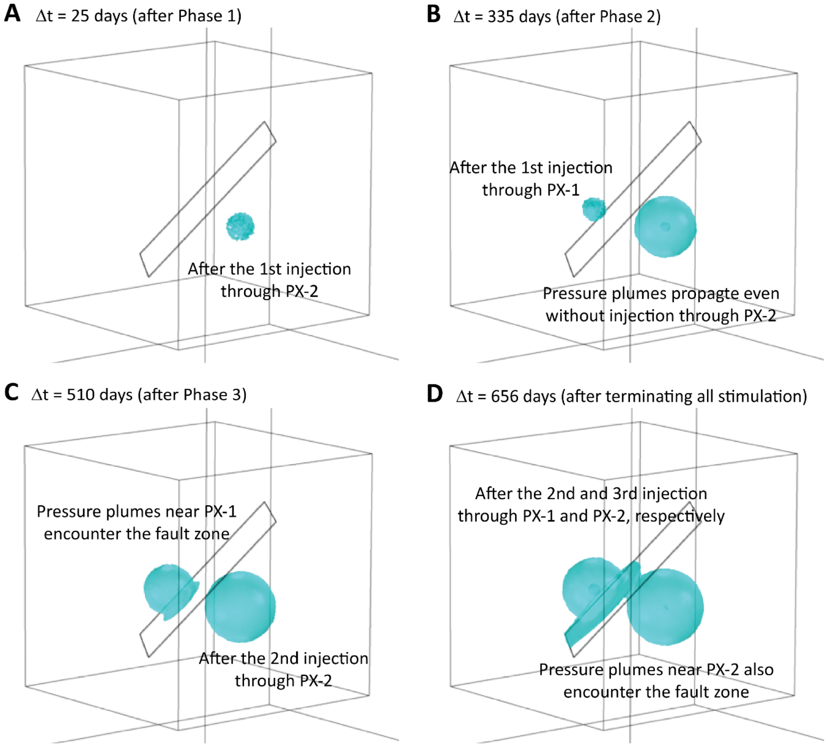


- Poroelastic coupling effects on induced earthquakes quantified by Coulomb stress change

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

Application: 2016-2018 Pohang





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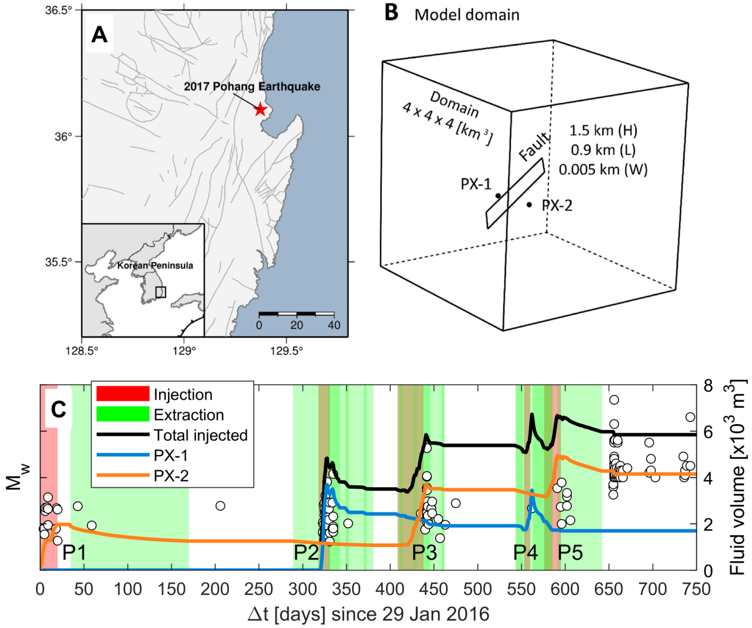

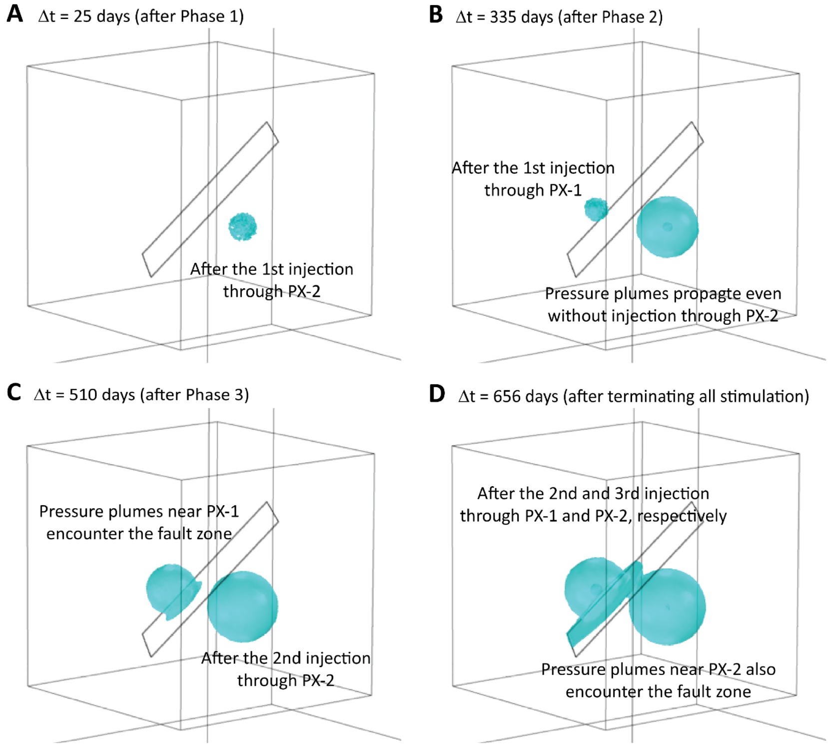

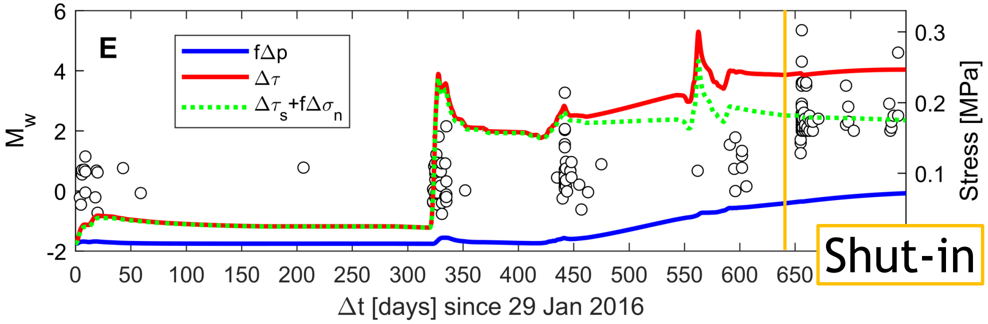

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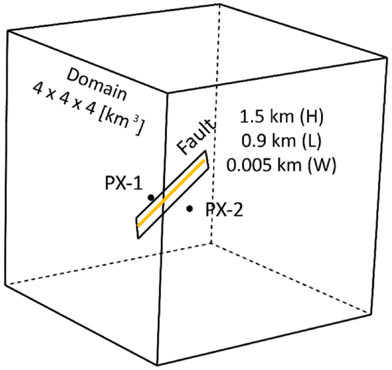
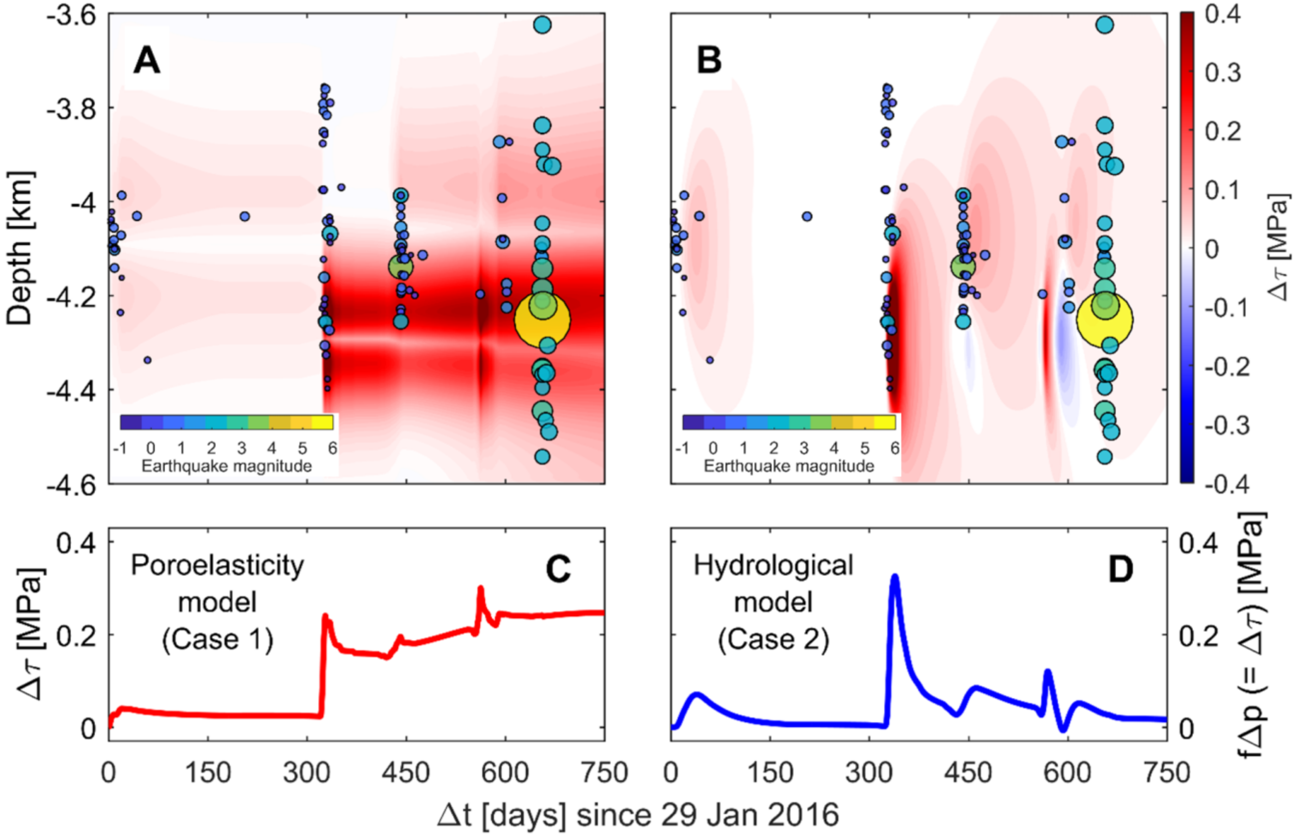
Coupled vs. Uncoupled Systems

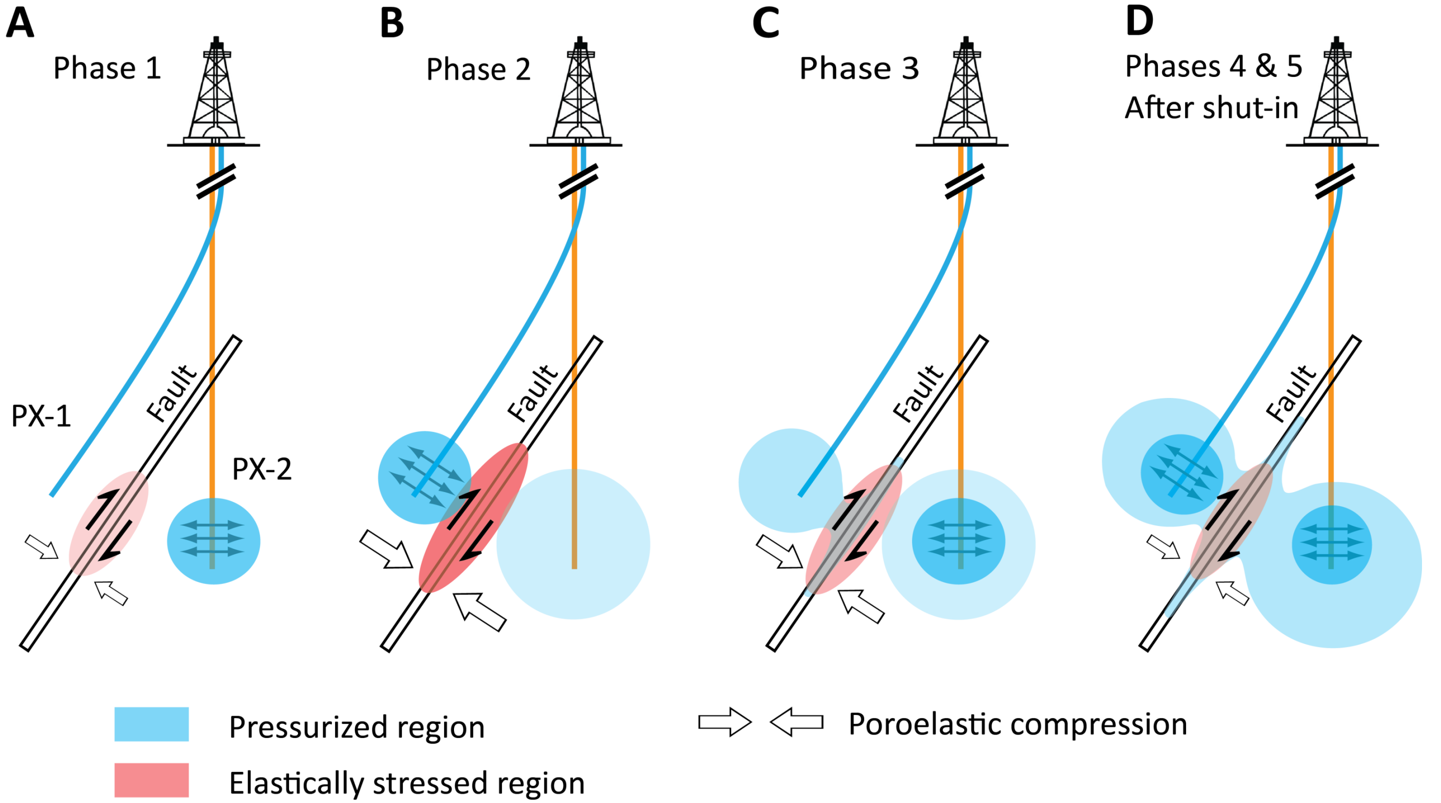




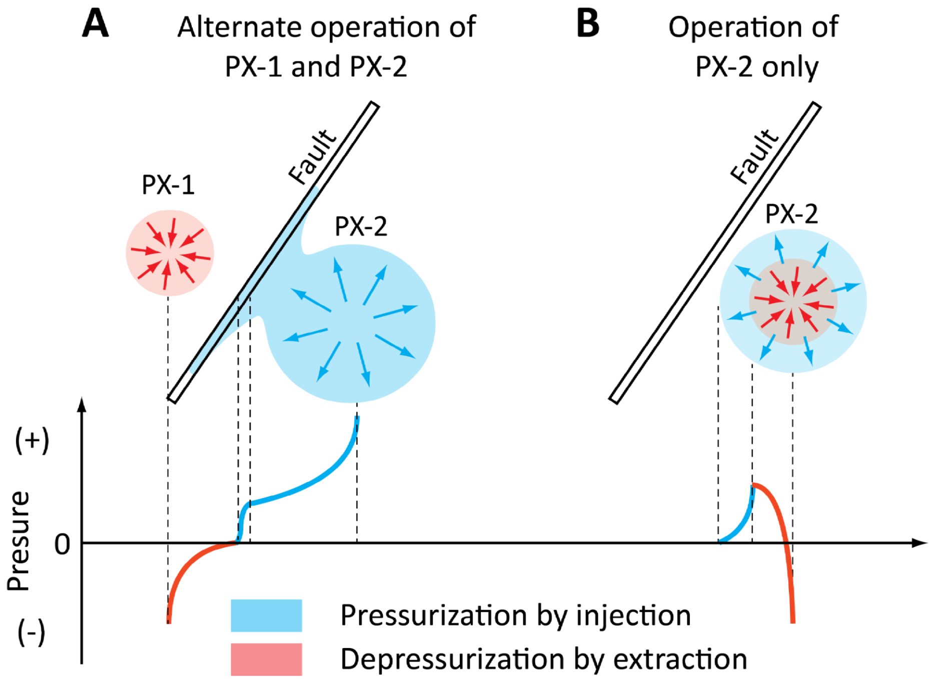
Chang et al. (2020) Sci. Rep.

- In addition to regional tectonics and/or nearby natural earthquake nucleation, human activities may induce large magnitude earthquakes after shut-in by accumulating poroelastic stressing as well as pore pressure along the fault.

Sequential Mechanisms



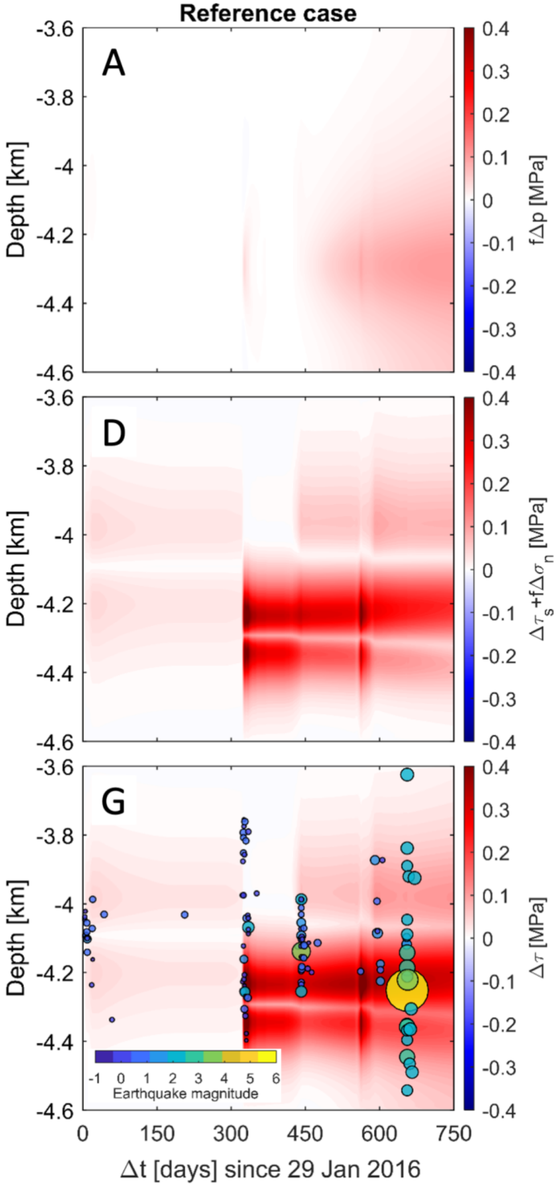
Can Operational Controls Mitigate EQs?

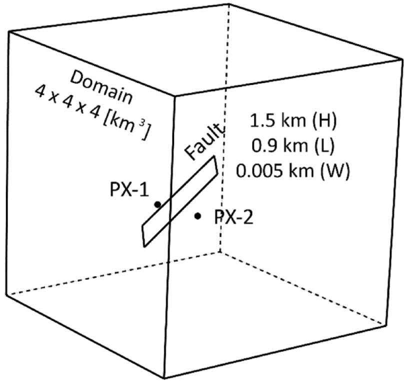


- Alternate injection-extraction operations through PX-1 and PX-2 can develop strong gradients in pore-pressure fields across the fault plane.

- Operation locations with respect to fault location may strengthen (or weaken) pore-pressure diffusion and elastic transfer to the fault through low-permeability basement rock

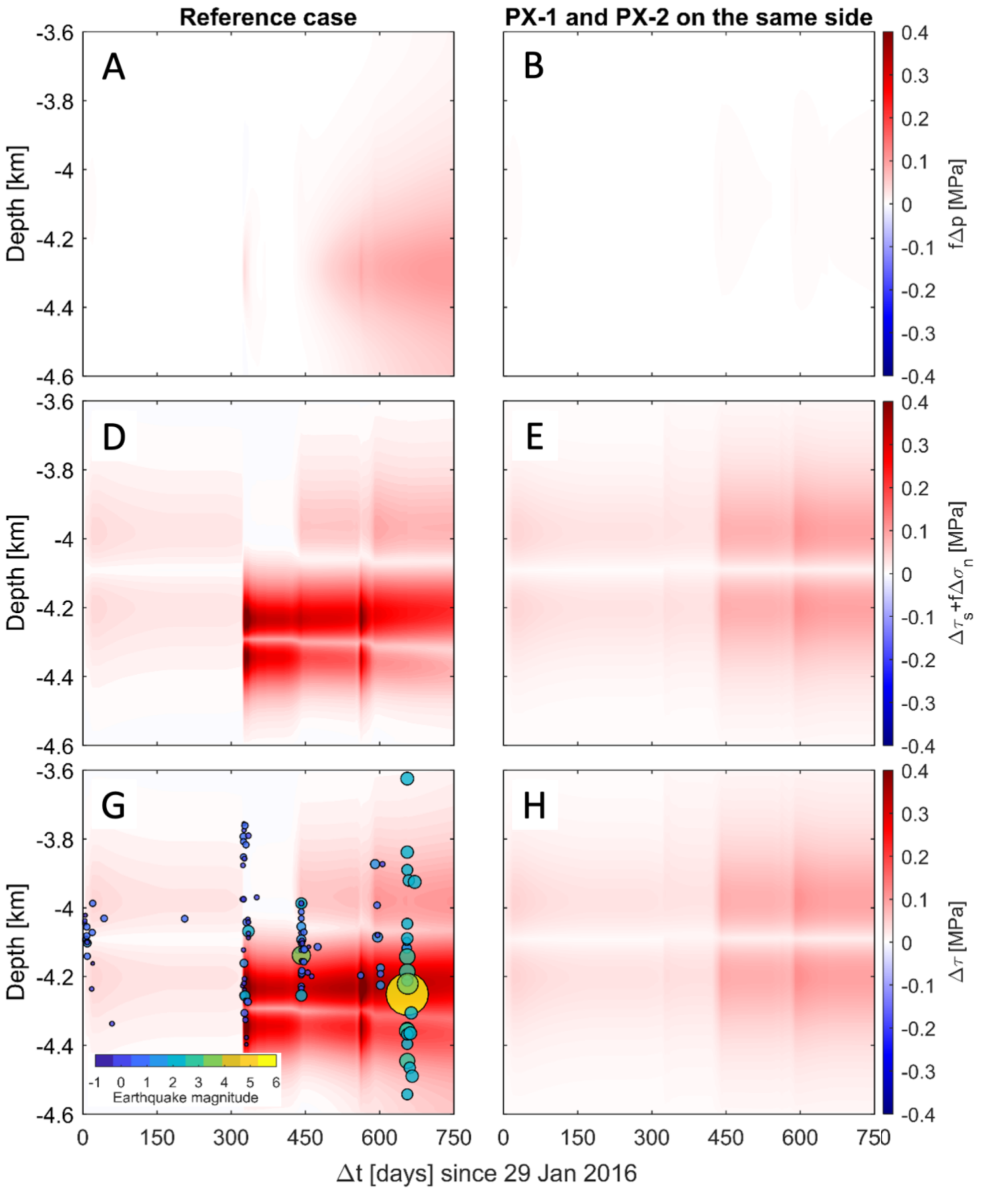
Results: Reference Model

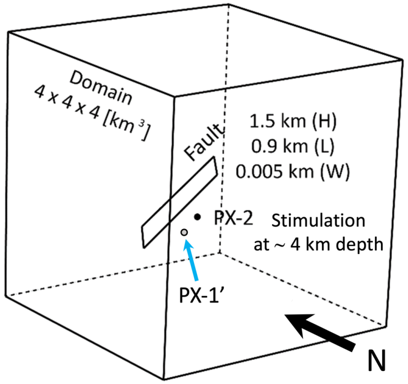




- Immediate poroelastic shearing causes early seismic events.
- Delayed pore-pressure diffusion and poroelastic stressing accumulates elastic energy, eventually nucleating earthquakes (M_w>3) after terminating

Results: Well Location

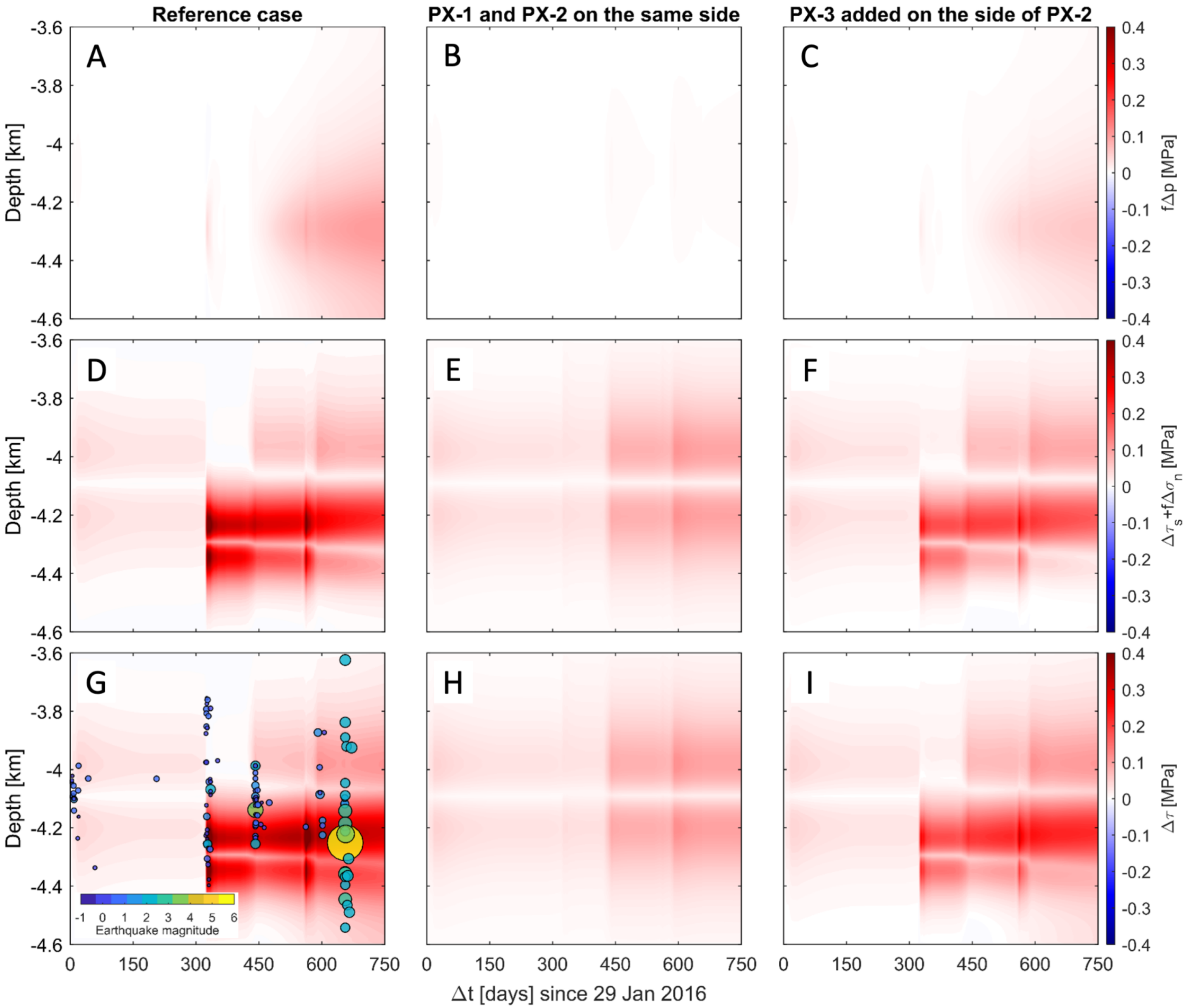


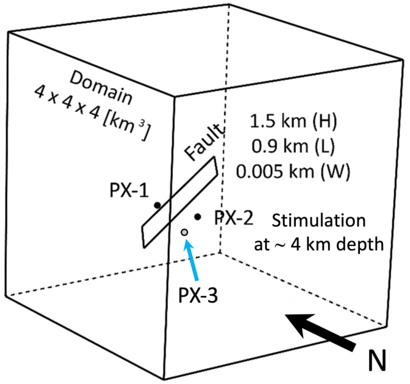


PX-1': PX-1 located at the same side of PX-2

- PX-1 and PX-2 are on the same side of the fault.
- Almost no direct diffusion of pore pressure into the fault.
- Only poroelastic stressing is critical to increase the Coulomb stress along the fault.

Results: Well Location/Number





- Additional well (PX-3) lessens pressure buildup as well as poroelastic stressing.
- However, similar patterns of $\Delta\tau$ are generated.

Conclusions

- Sequential stimulation activities at the Pohang site could cause continuous pore-pressure diffusion and poroelastic shearing that brought about accumulation of substantial energy on the fault, potentially inducing moderate to large earthquakes even after shut-in.

- Site-specific operational and geological factors can enhance (or attenuate) the seismogenic response to the stimulation activities, and the local perturbation in stress states on the fault may be an additional critical mechanism to induce larger post shut-in earthquakes.

- Interactions between well operations will determine the direction of preferential flow that may enhance pore-pressure diffusion and elastic stress transfer to the fault, such that mitigating wells should be aligned not across the fault to minimize operational perturbations of the fault stability

Question & Answer

Contact: kchang@sandia.gov

Chang, K.W., H. Yoon, Y.-H. Kim, and 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

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

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Chang, K.W. and P. Segall (2016), Injection induced seismicity on basement faults including poroelastic stressing, ***JGR Solid Earth***, 121(4): 2708-2726

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