Quantifying the Effects of Spatial Uncertainty in Fracture Permeability on CO_2 Leakage through Columbia River Basalt Flow Interiors

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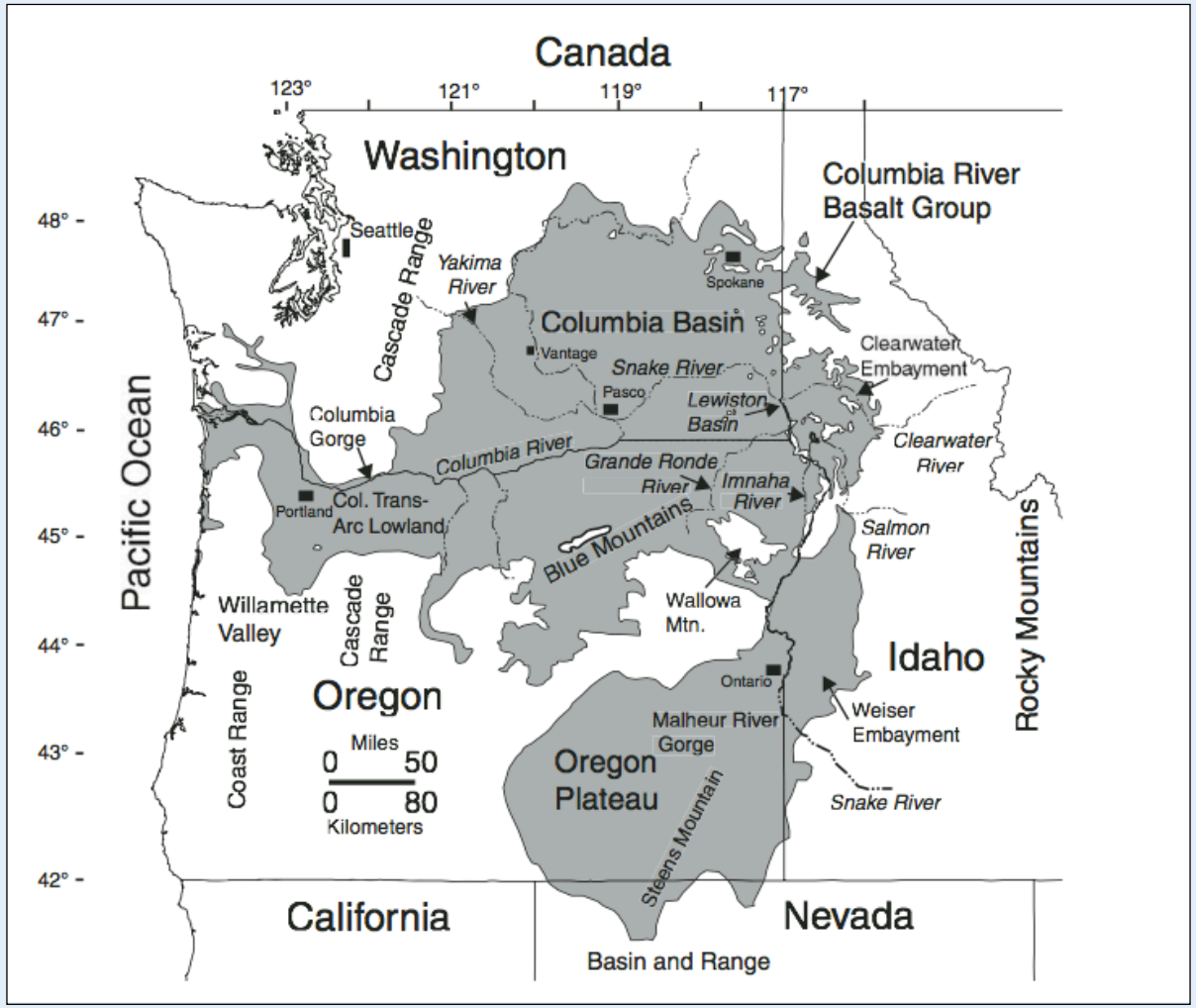
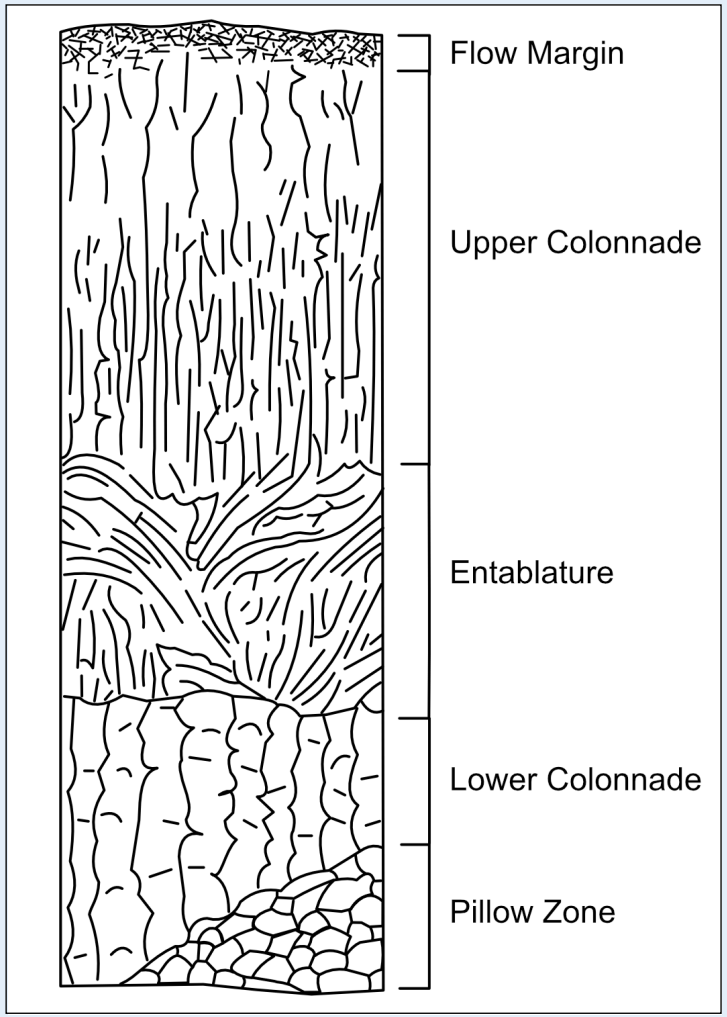
The Columbia River Basalt Group



After Reidel et al (2013)



After Long (1986)

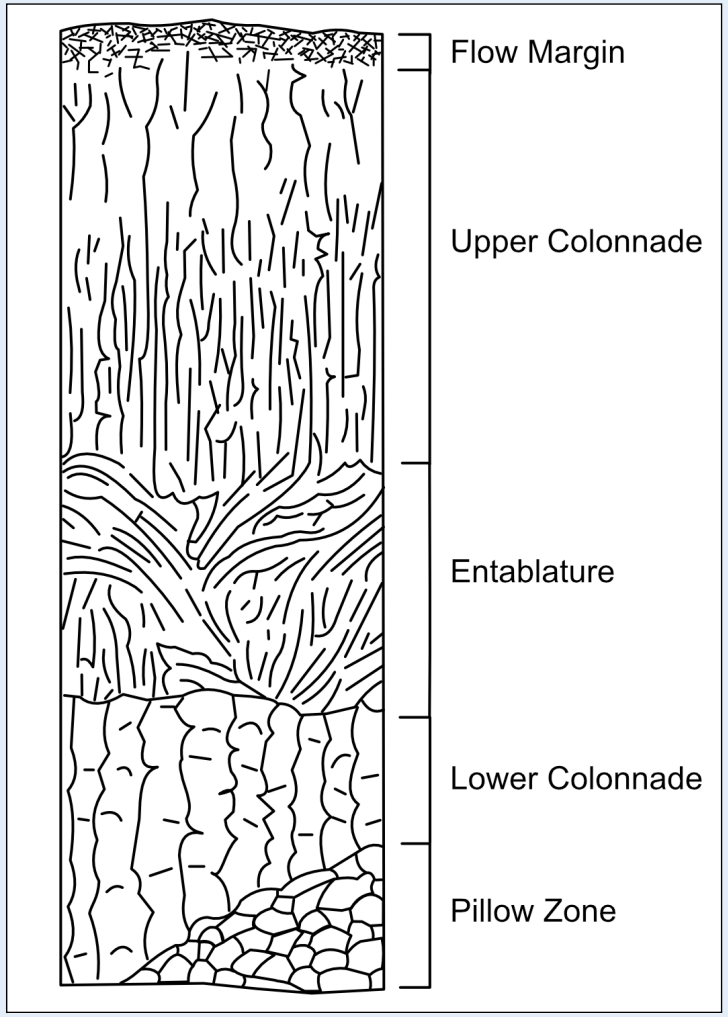
Research Question

How does uncertainty in fracture permeability affect CO_2 leakage in a basalt fracture network?

- Spatially?
- Temporally?
- Near the critical point of CO_2?

Approach

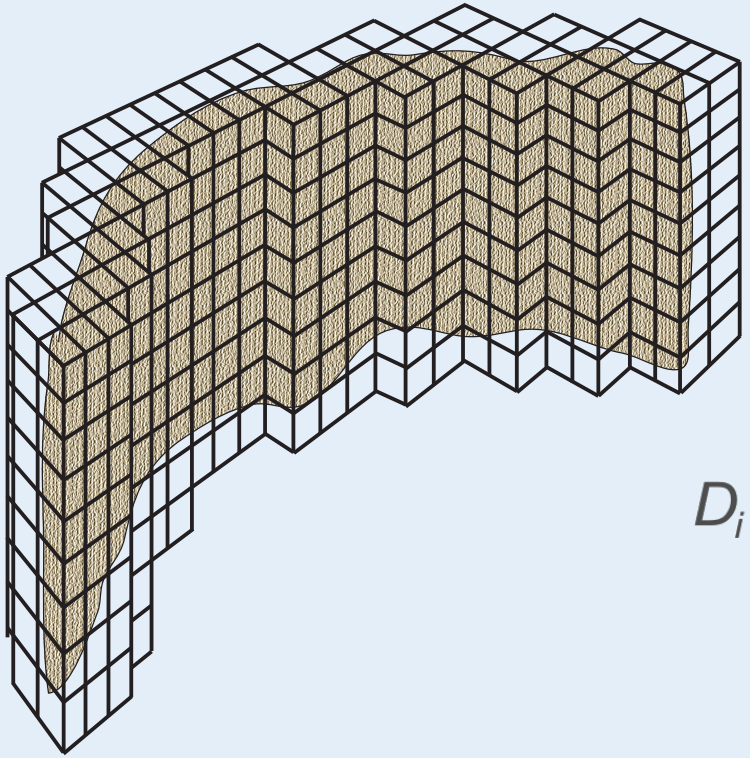
I. LiDAR scanning to make fracture maps
II. Model of fracture permeability applied to a fracture map
III. Monte Carlo simulation of N=50 iterations with spatially random permeability

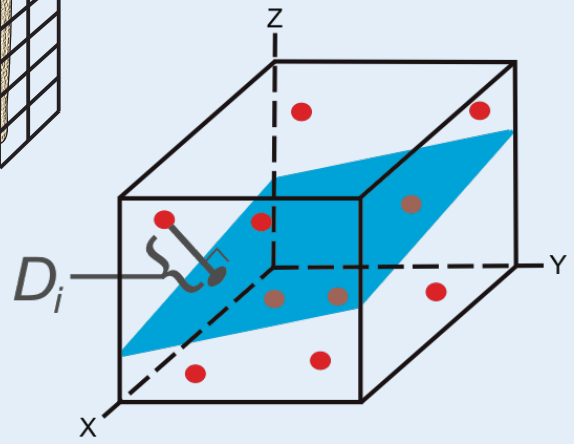


After Long (1986)

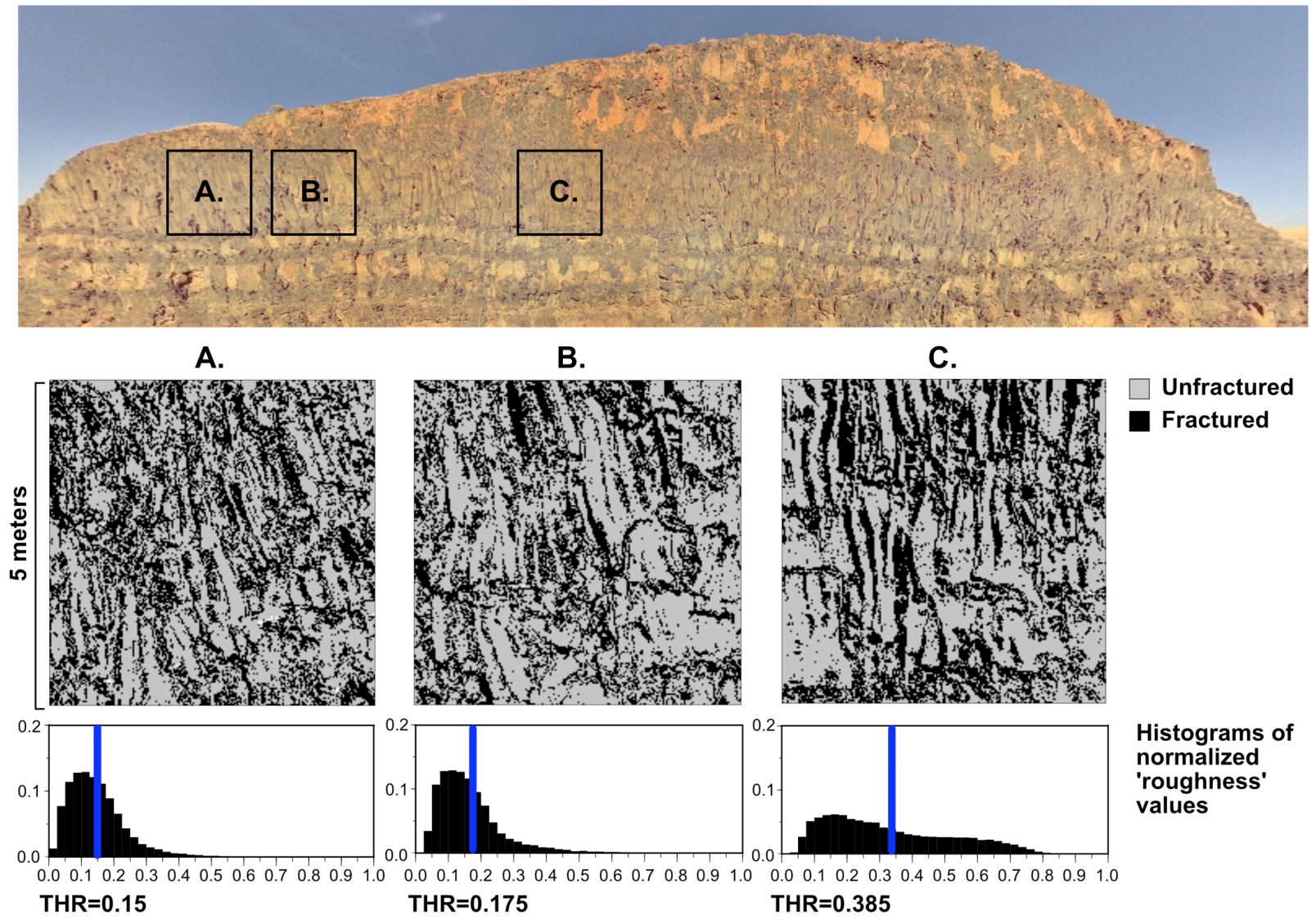
Field Work

- Field work: acquire terrestrial LiDAR scans of outcrop fracture networks to image fracture networks.
- Data processing: use surface roughness algorithm developed by Pollyea and Fairley (2011) to produce fracture maps





Fracture mapping

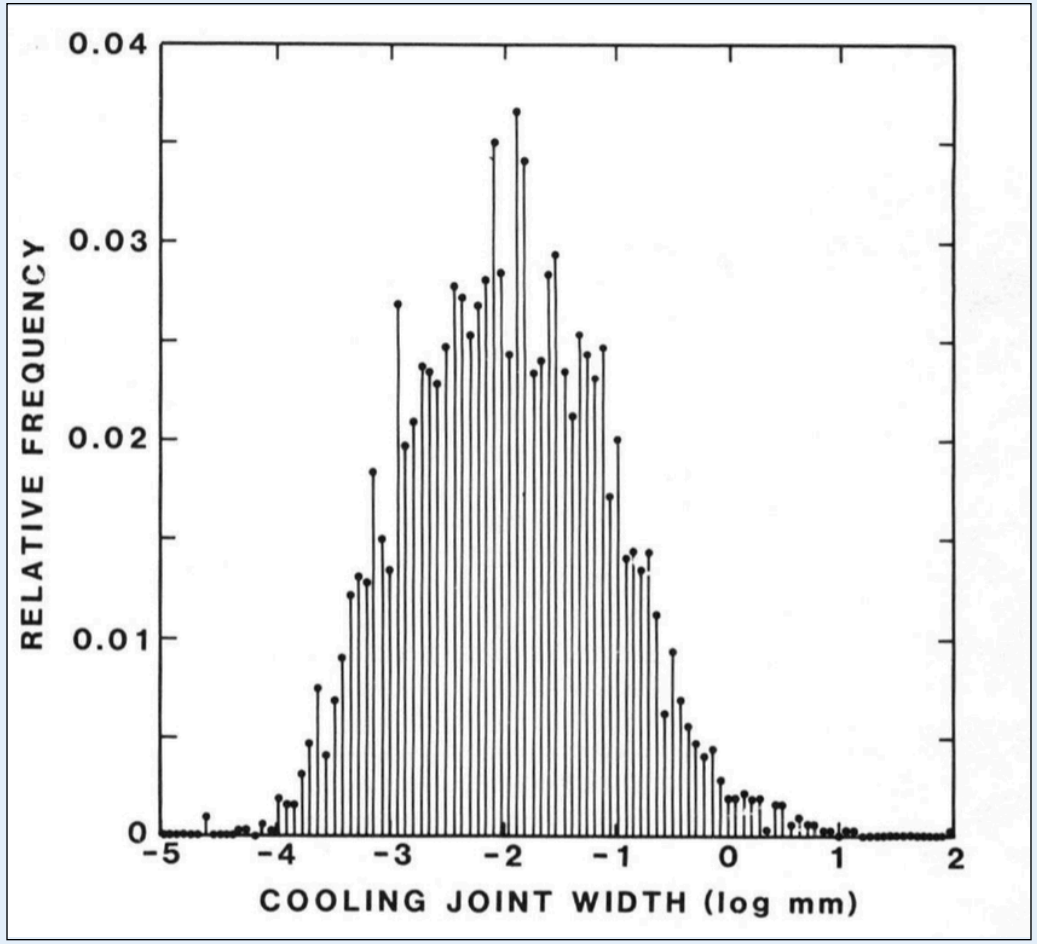


- Discretization of roughness boxes was 2.5 cm
- Binary transform of roughness values based on histogram produces a grid where each cell is considered either fractured or not

Permeability model

Lindberg et al 1989

- Statistical analysis of CRB flow interior cooling joints
- Lognormal distribution
- Mean of 0.226 mm
- Standard deviation of 0.489 mm
- No spatial correlation



From Lindberg et al (1989)

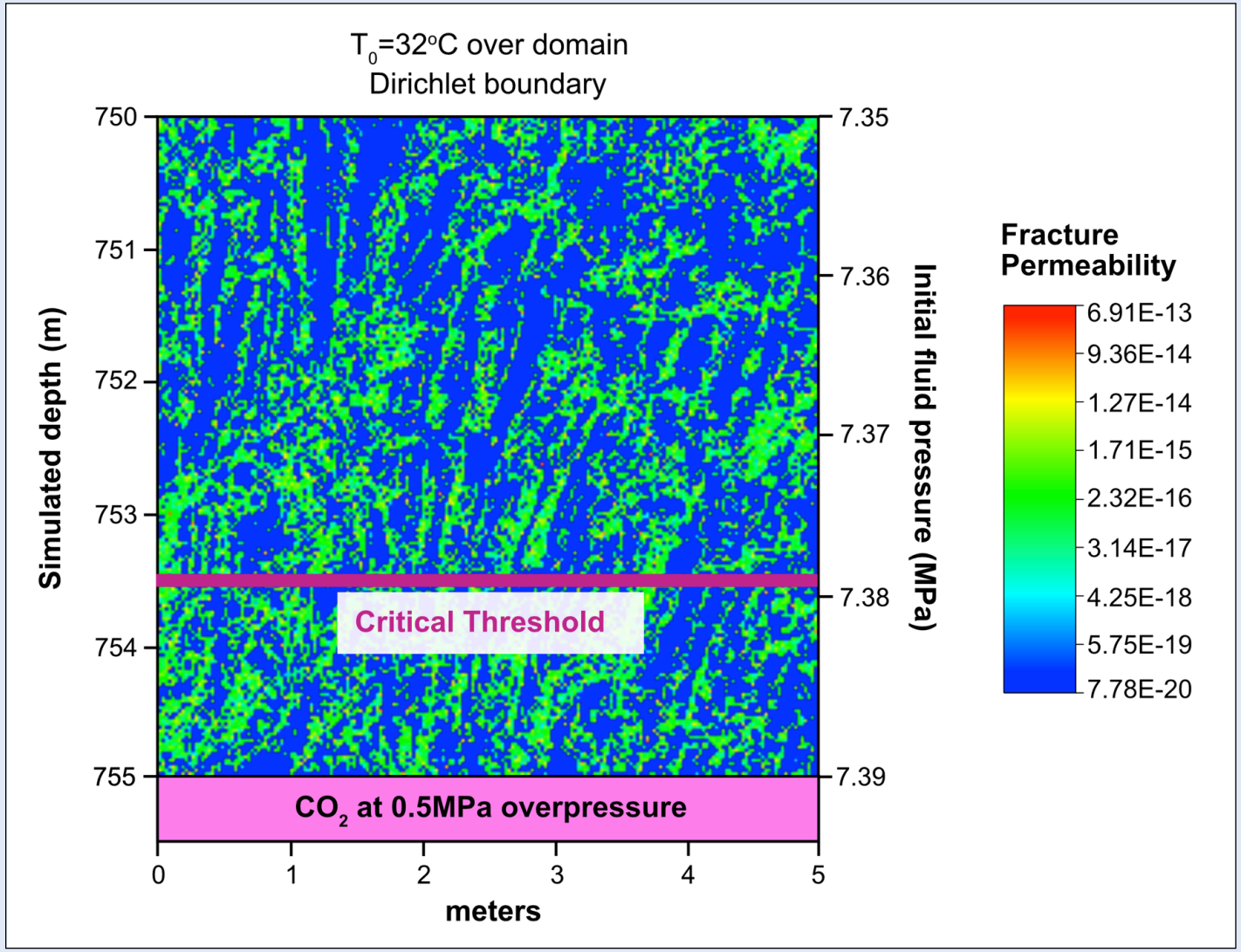
Permeability model continued

- Use random number generator to produce a lognormal set of apertures
- Convert to permeability using cubic law
- Hydraulic tests suggest that *in situ* fracture permeability is much lower
- Estimated new mean k_f based on weighted geomean

$$k_{eff} = \exp\left(\frac{\sum_{i=1}^{n} w_i \ln k_i}{\sum_{i=1}^{n} w_i}\right)$$

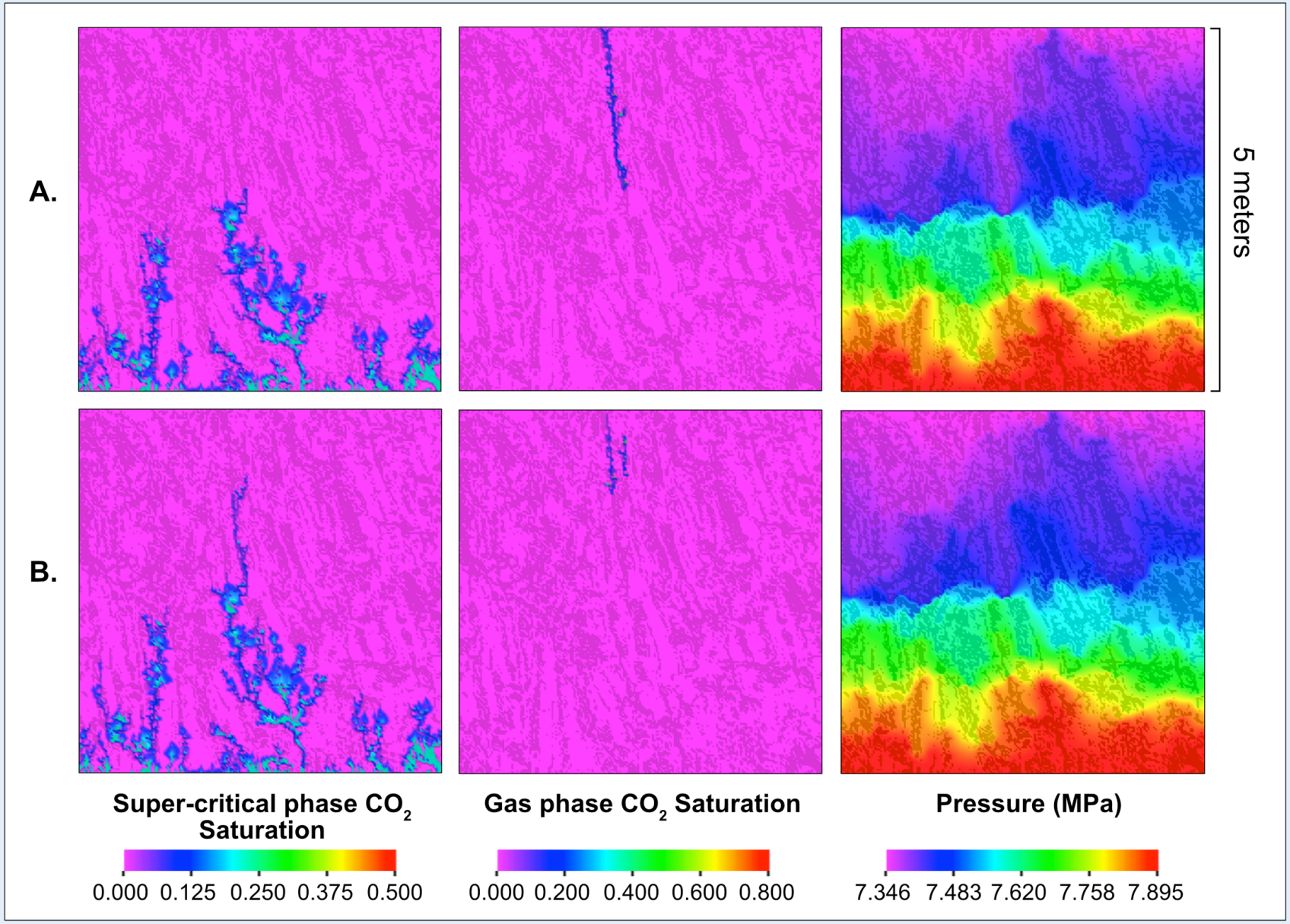
$$k_f = \exp\left(\frac{\ln k_{eff} - w_m \ln k_m}{w_f}\right)$$

Model



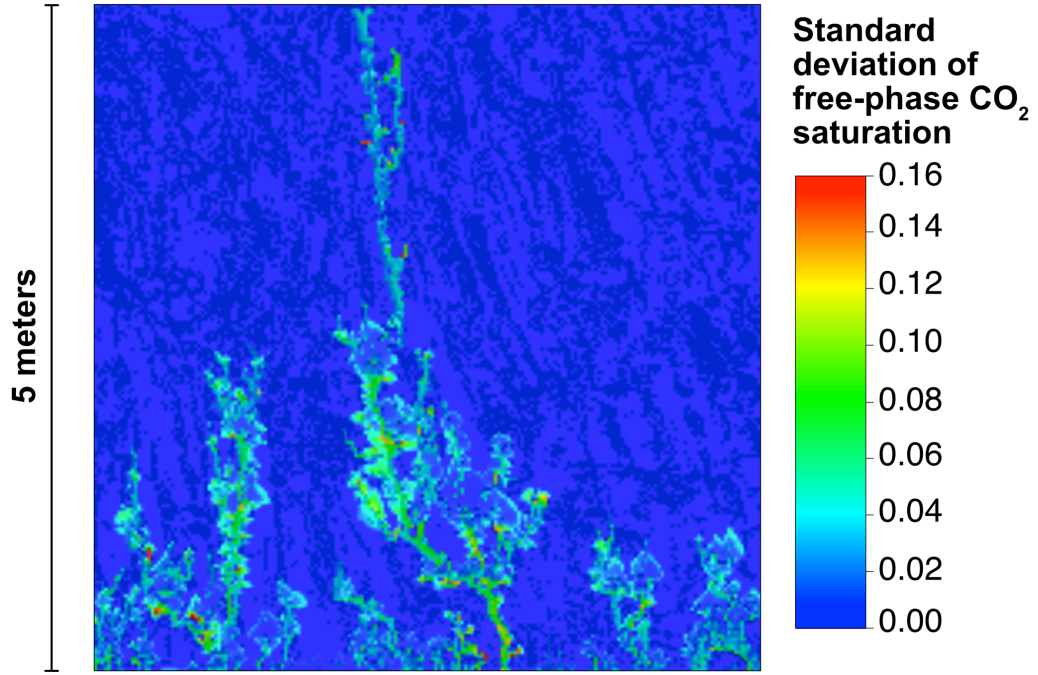
- Model built using TOUGH3 (Jung et al, in press)
- ECO2M equation of state (Pruess 2011)
- This model does not account for chemistry due to short time-scales

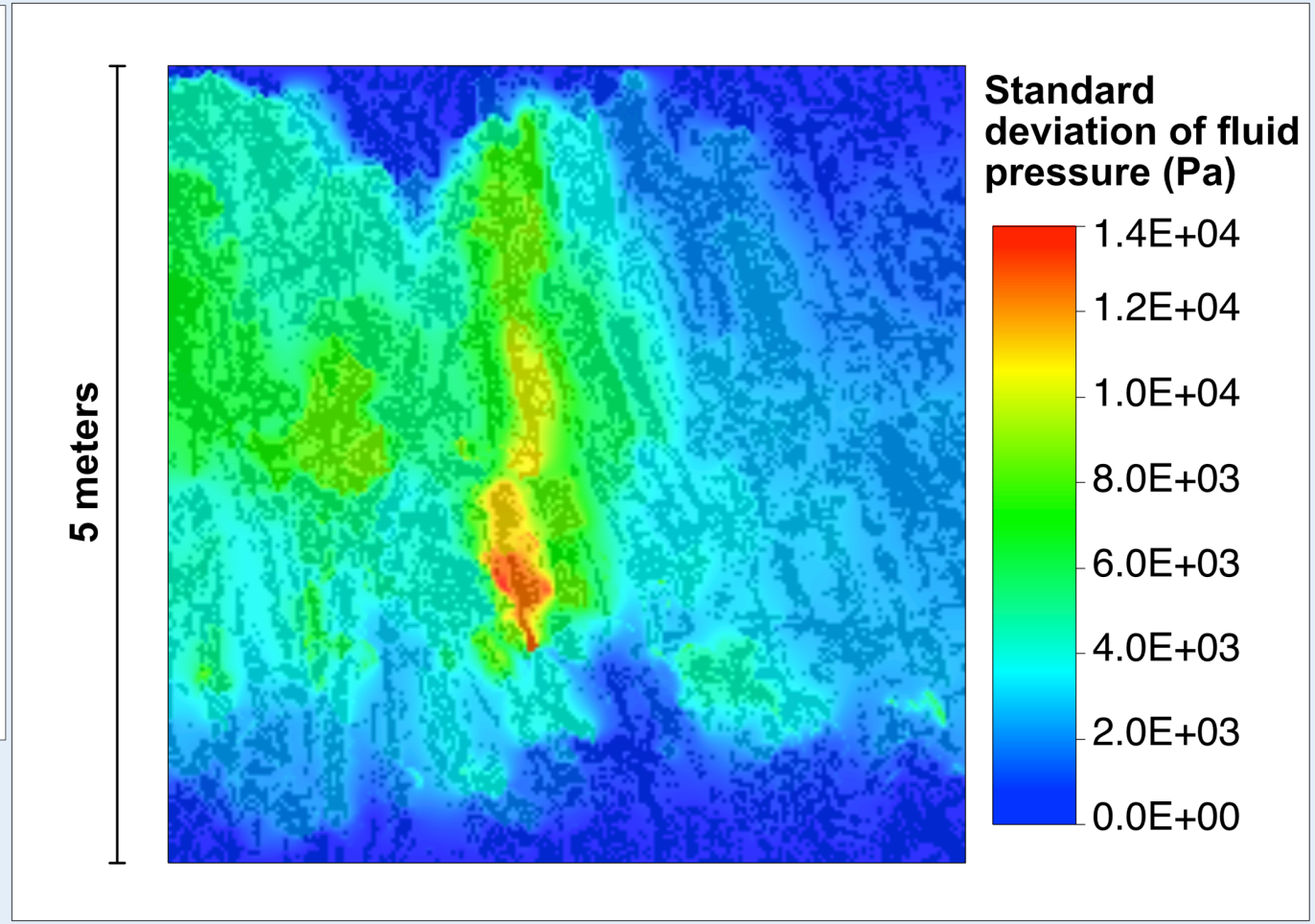
Example results from Monte Carlo simulations



- Phase transition occurs at different depths (approximately 1 meter difference)
- Corresponding pressure profiles suggest this is caused by pressure
- Spatial permeability differences affect fluid pressure

Results





- E-type analysis
- Standard deviation of free-phase CO_2 saturation (left) and fluid pressure (right) across N=36 simulations

Conclusions

- Spatial uncertainty in fracture permeability has little effect on free-phase CO_2 saturation
- Distribution of fluid pressure, and thus the location of the critical point, is affected by the spatial distribution of fracture permeability