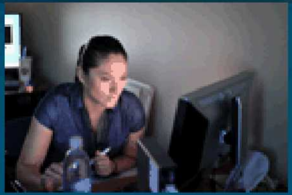
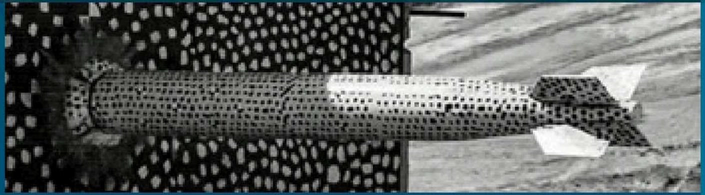
SAND2020-4582C

Reservoir Response to Heat Generating Nuclear Waste in Bedded Salt





Presented by:

Richard S. Jayne

EGU 2020 Virtual Meeting
Monday 4 May 2020

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Brine Availability Test in Salt (BATS) Team

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Brine Availability Test in Salt (BATS)

BATS Goal:

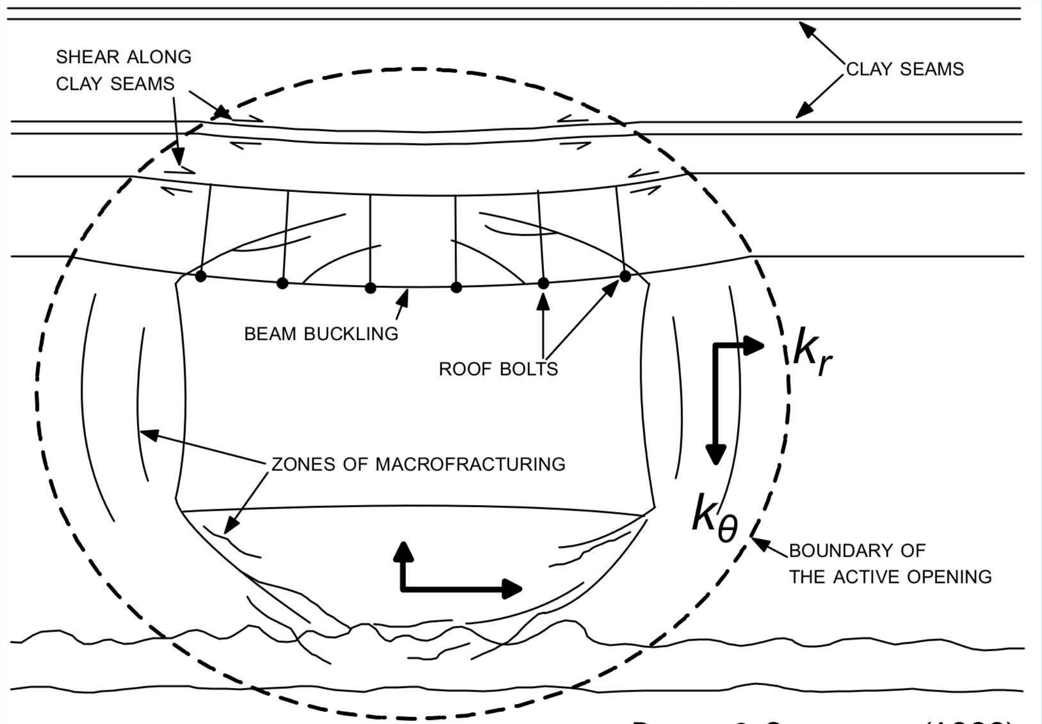
- ***Monitoring brine distribution, inflow, and chemistry from heated salt using geophysical methods and direct liquid & gas sampling***

Why Salt?

- Salt long-term (10^4 – 10^6 yrs.) benefits at km-scale
  - Low porosity and permeability
  - High thermal conductivity
  - No flowing groundwater
  - Creep closure

Salt Complexities

- Brine and salt are corrosive
- Evaporites are very soluble in water
- Salt creep requires drift maintenance
- Excavation Damaged Zone (EDZ)



Borns & Stormont (1988)

Background on Brine in Salt

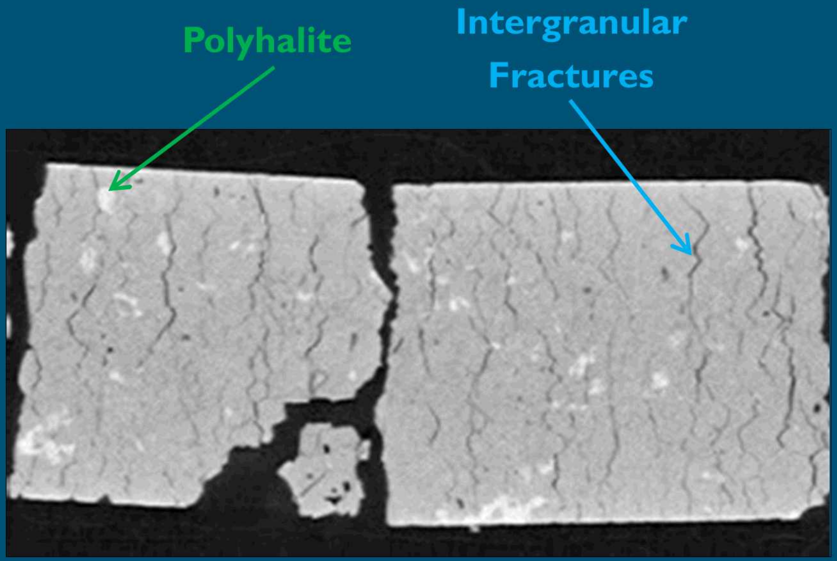
- Water types in bedded salt
  1. Disseminated clay (< 5 vol-% total; ~25 vol-% brine)
  2. Intragranular brine (fluid inclusions; 1 – 2 vol-%)
  3. Hydrous minerals (e.g., polyhalite, bischofite, epsomite)
  4. Intergranular brine (between salt crystals; << 1 vol-%)

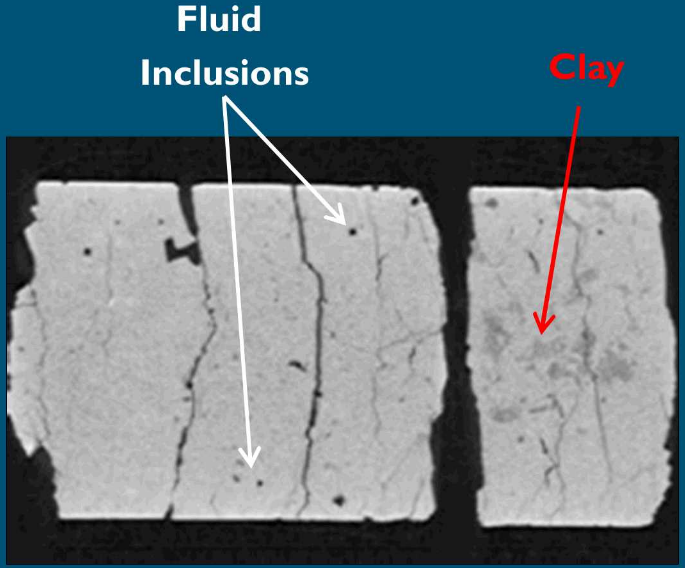
- These water types:
  - respond differently to heat & pressure
  - have varying chemical composition
  - differ in stable water isotope makeup

WIPP fluid inclusions, 2 mm scale bar (Caporuscio et al., 2013)

- EDZ increases intergranular ϕ → primary flow path

Q: How do water types contribute to *Brine Availability?*



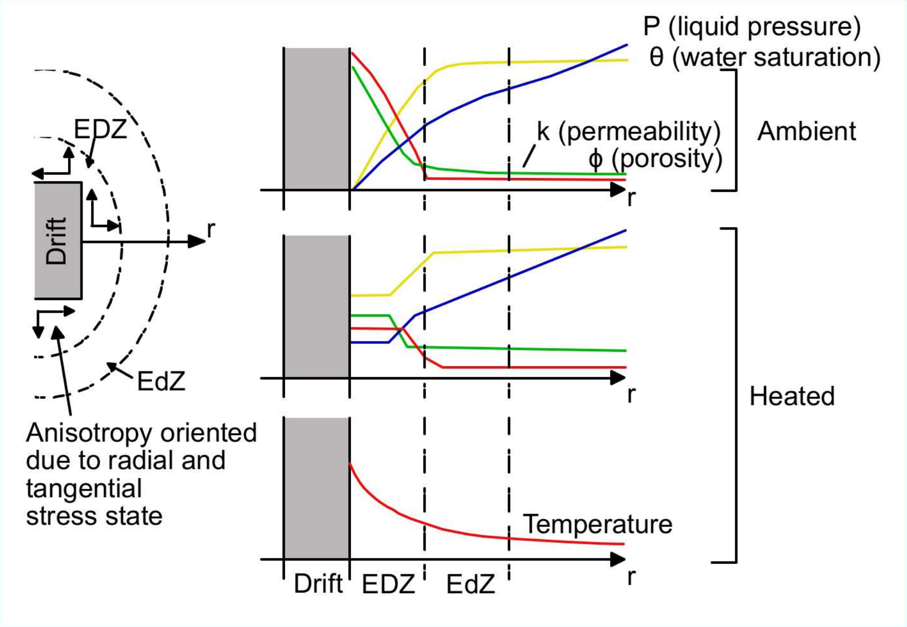


10.1 cm diameter core CT data (Betters et al., 2020)

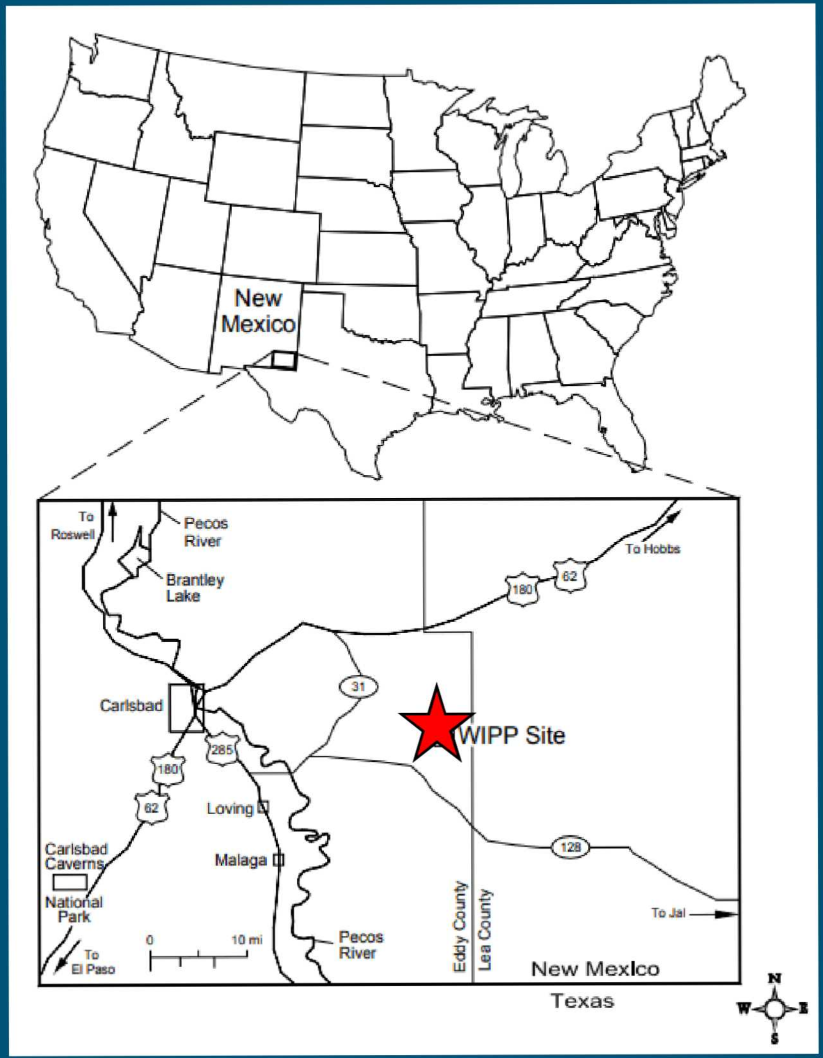
Questions BATS Experiment Seeks to Answer

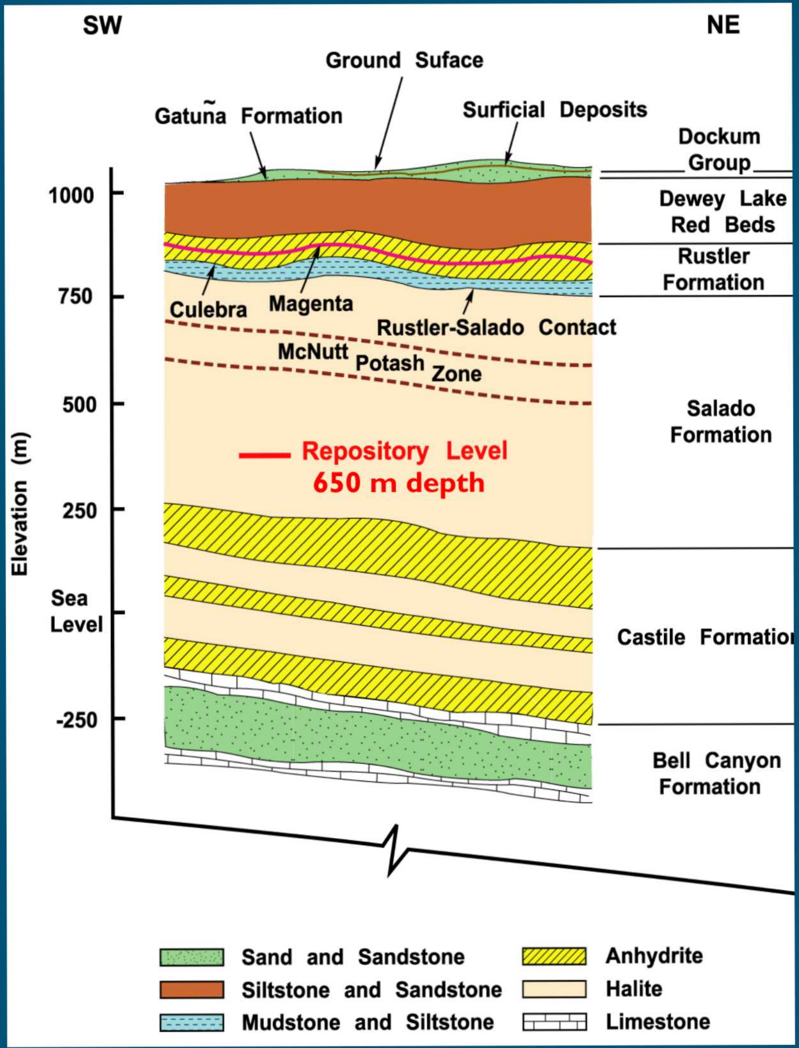
- Understand and predict THMC processes impacting brine availability
  - How much of each water type in bedded salt?
  - Water response to pressure (Δp), stress ($\Delta\sigma$), and temperature (ΔT)?
  - How does EDZ control migration of water (ϕ, k, relative perm. k_r)?
  - How does EDZ evolve with Δp, $\Delta\sigma$, and ΔT?
  - Is two-phase flow in EDZ important for predictions?
  - How to best simulate brine pulse after heating?

OBJECTIVE: Utilize PFLOTRAN and TOUGH numerical modeling codes to match the most recent heating/cooling cycle at WIPP.

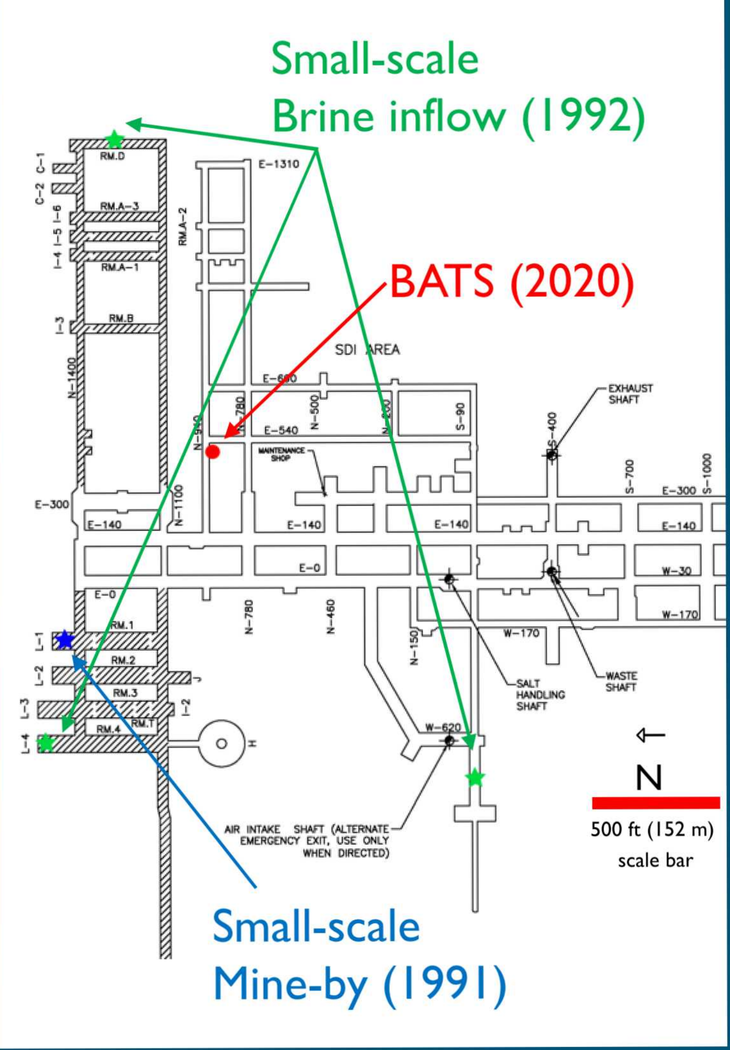


Waste Isolation Pilot Plant (WIPP) Context

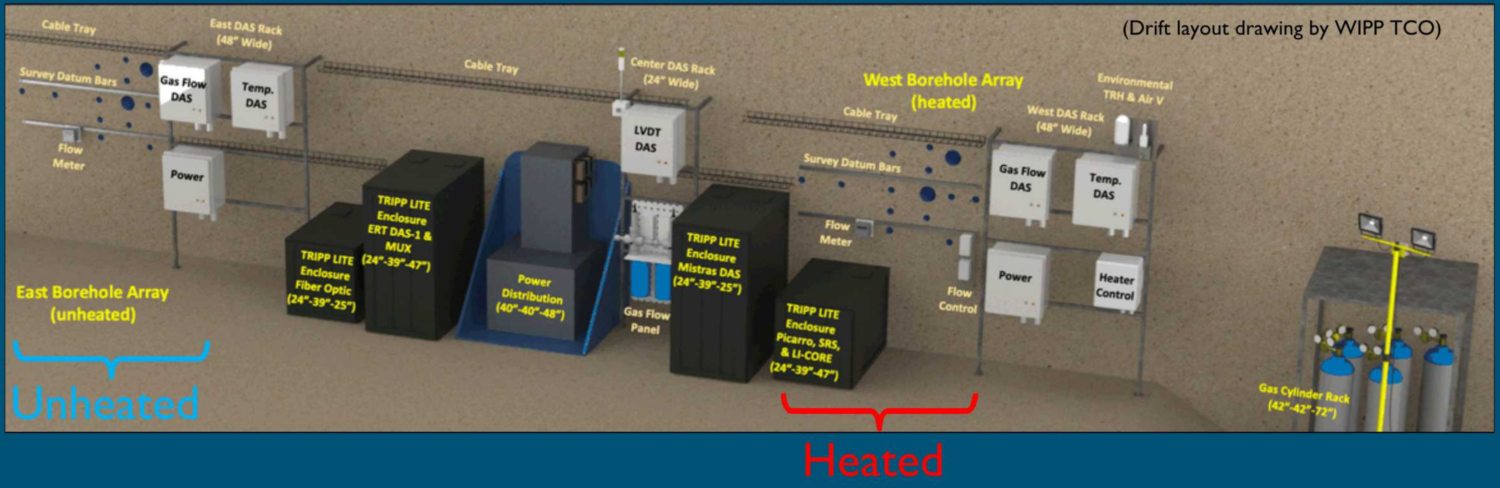


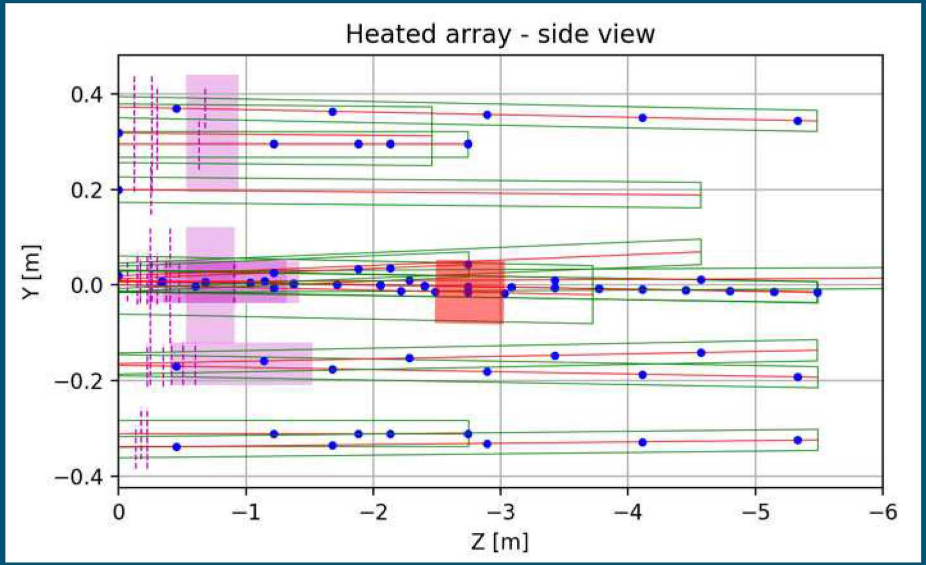


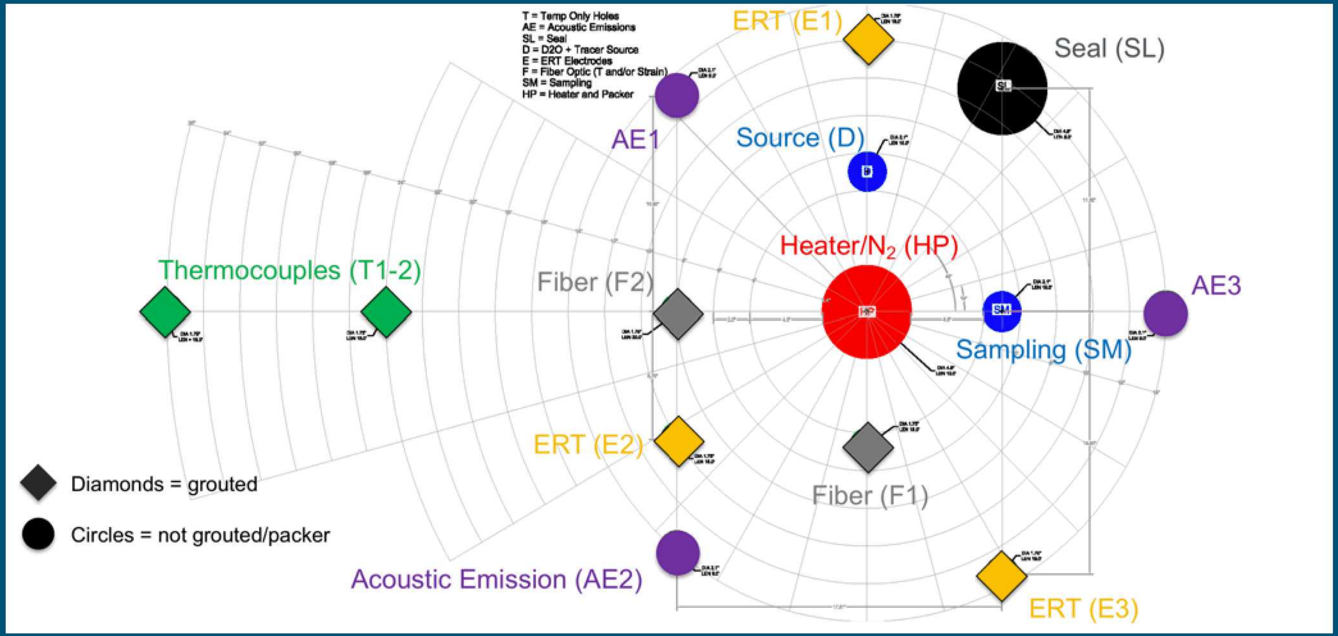
Layout of WIPP North End

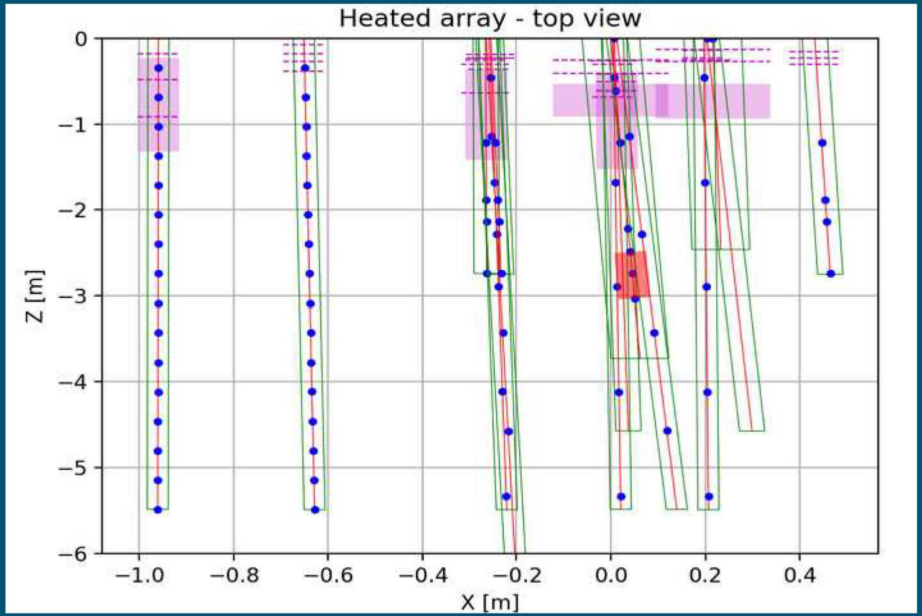


BATS Experimental Setup

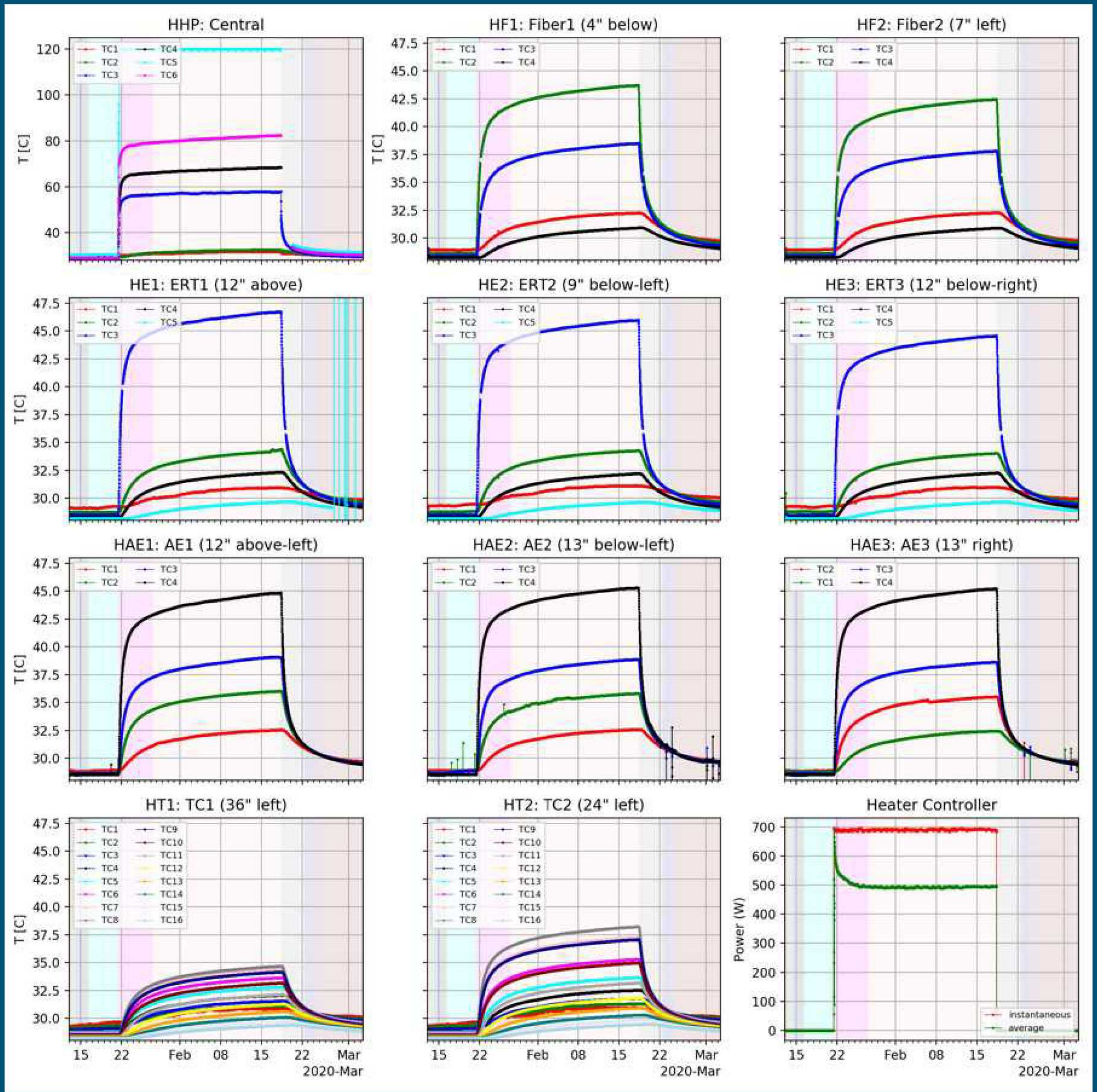


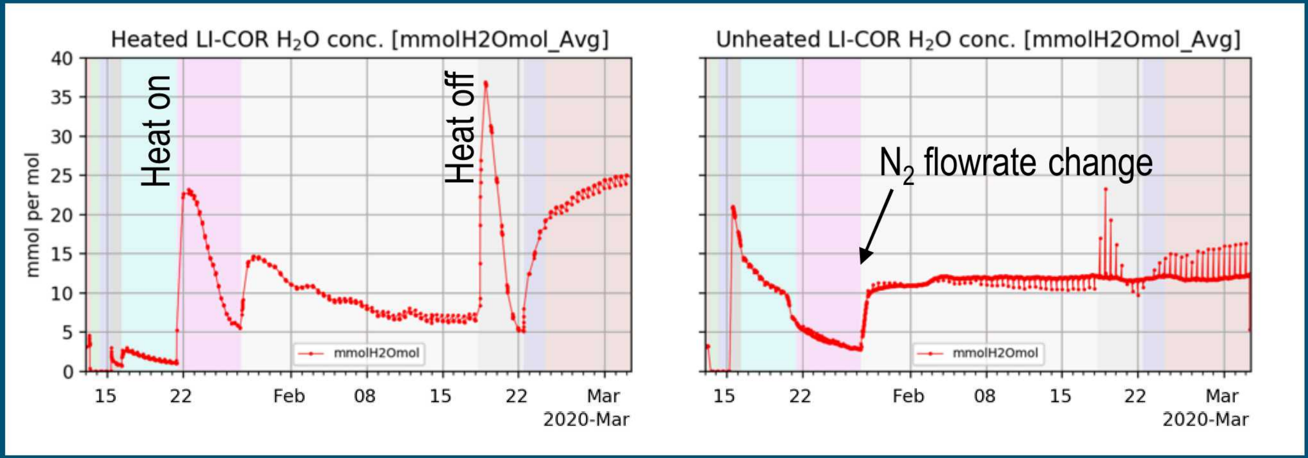


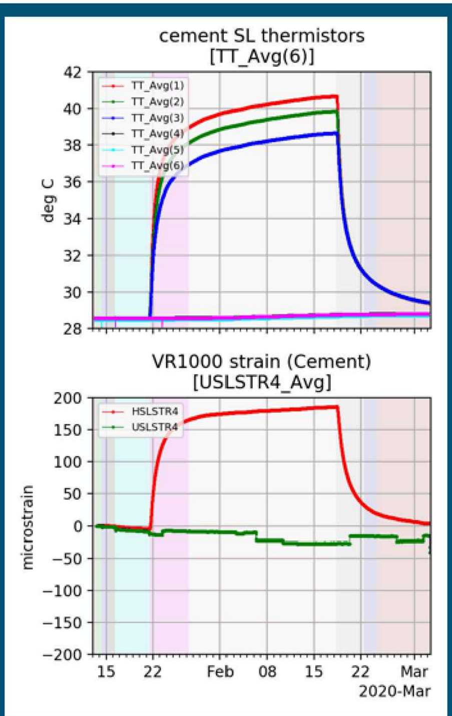


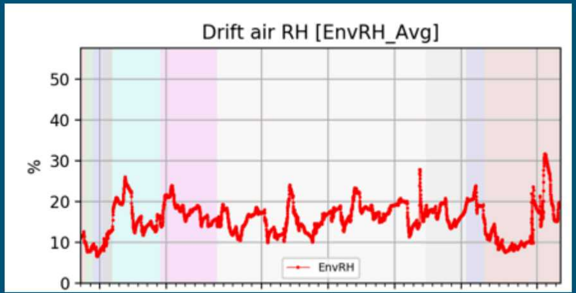


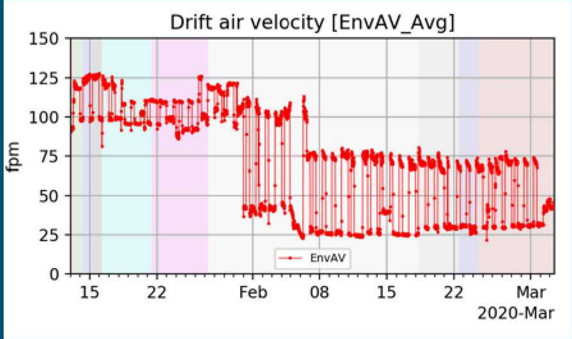
January - March 2020 BATS Test Data



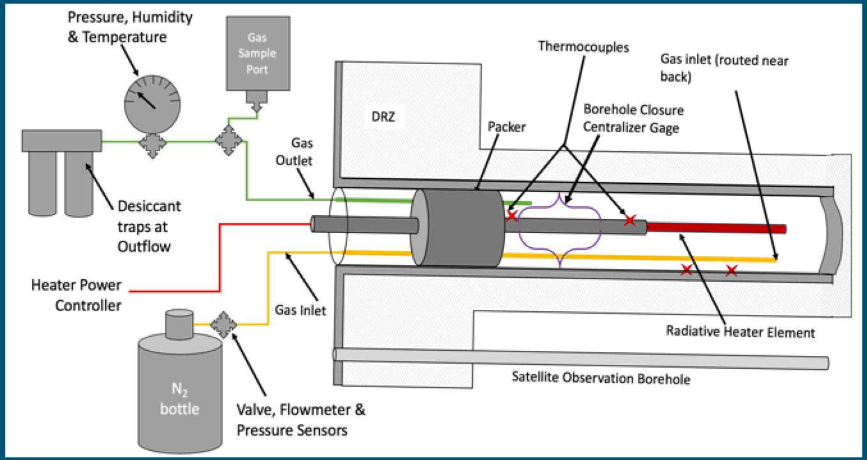








Utilizing 1-D Models to Match Field Test



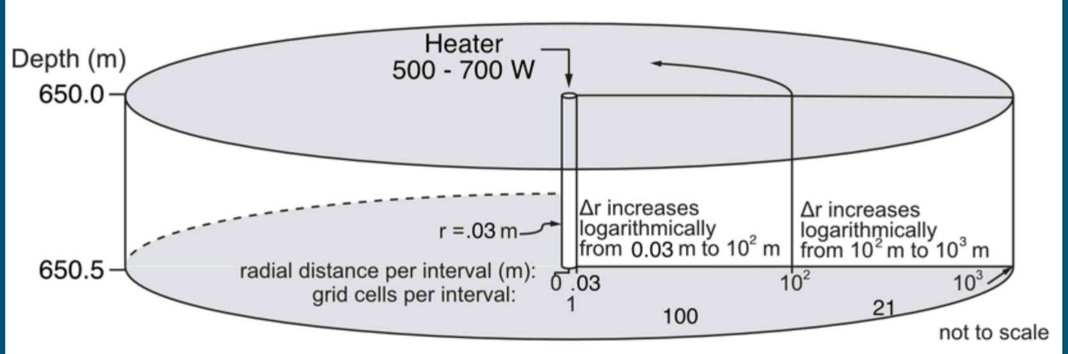
Cross-section central (HP) borehole

1D radially symmetric
- 121 grid cells
- 1 km total model domain (0.03 – 150 m)
- DRZ 0.03 – 1.75 m

Heater in contact with salt
- air causes issues with matching field data (radiative heating)

Simulate 29 days of heating and 13
- Incorporates the on/off cycles in early time and gradual lowering of energy input

Match temperatures measured at 3 thermocouples in-plane with heater
- HE1 – TC3 – 0.4m
- HT2 – TC8 – 0.68 m
- HT1 – TC8 – 1.01 m



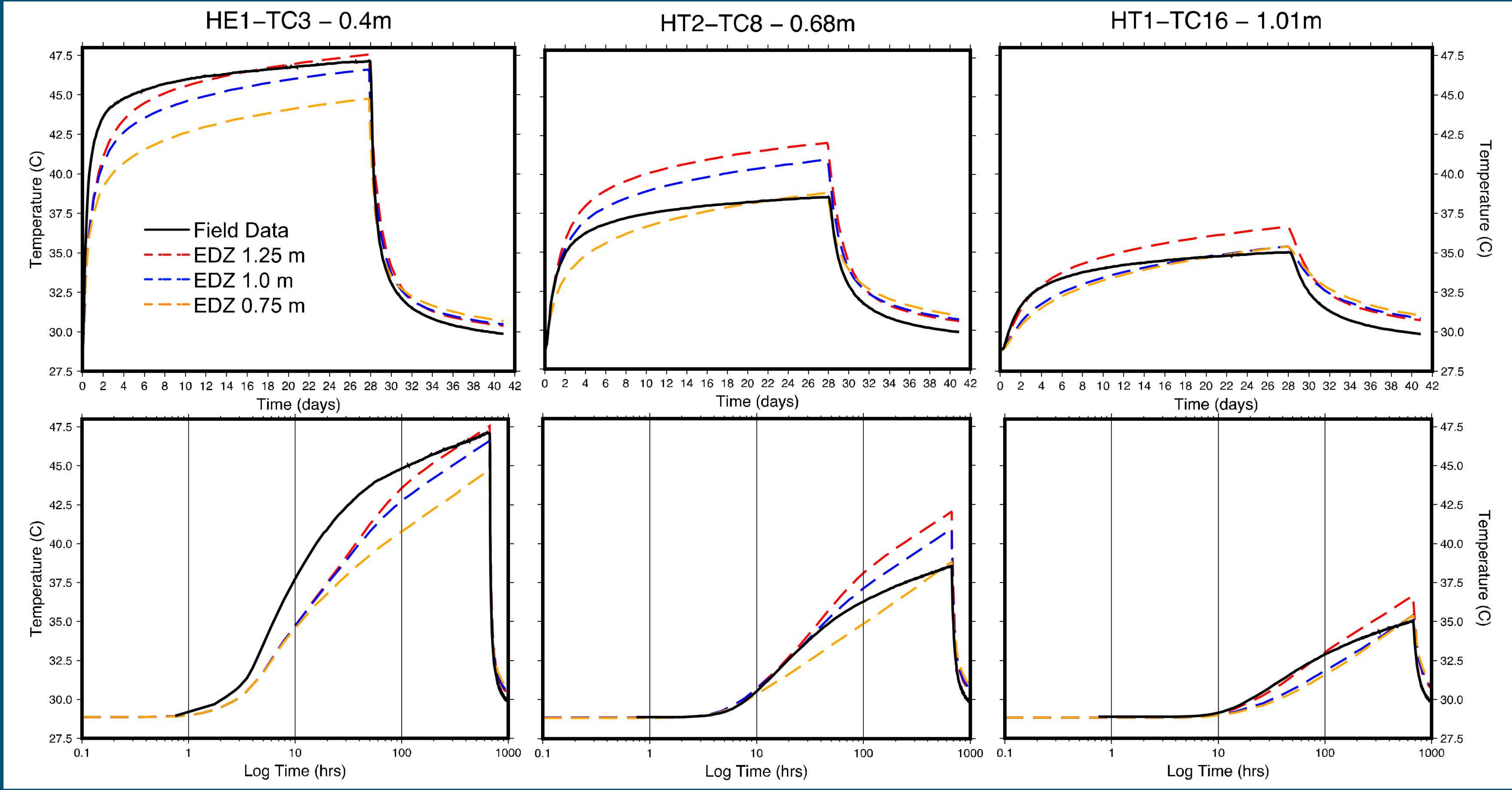
Reservoir Parameters

P_f = 0.1 - 12.4 MPa
T = 29.5 °C
$k = 10^{-17} - 10^{-22}$ m^2
φ = 0.001 - 0.01
K = 2.0 - 7.0 W/m °C
c = 366 - 1000 J/kg °C

Relative Permeability
λ = 0.412
S_{lr} = 0.2
S_{ls} = 1.0
S_{gr} = 0.2

Capillary Pressure
λ = 0.412
S_{lr} = 0.2
α (Pa^{-1}) = 6.5 x 10^{-5}
S_{ls} = 0.999

Excavated Damaged Zone (EDZ) Strongly Controls Temperature profile



3-D Modeling of Field Test

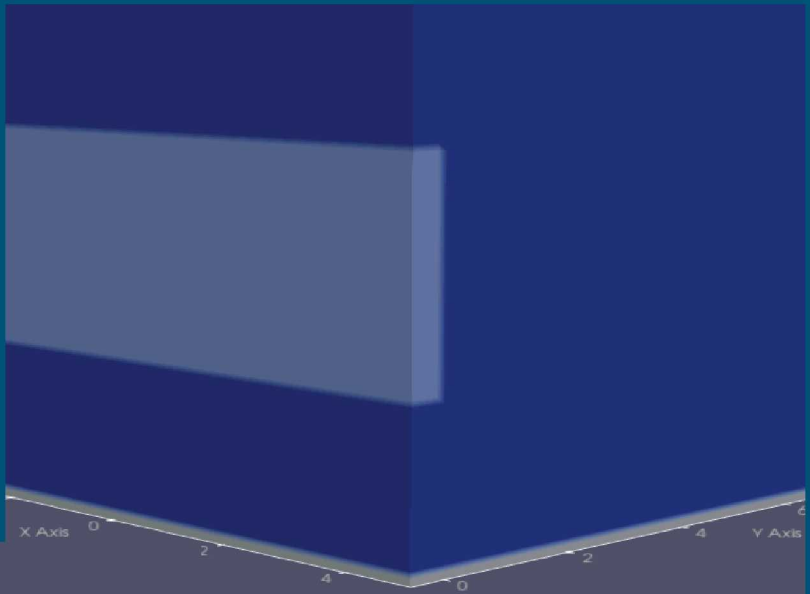
Preliminary Results/Workflow

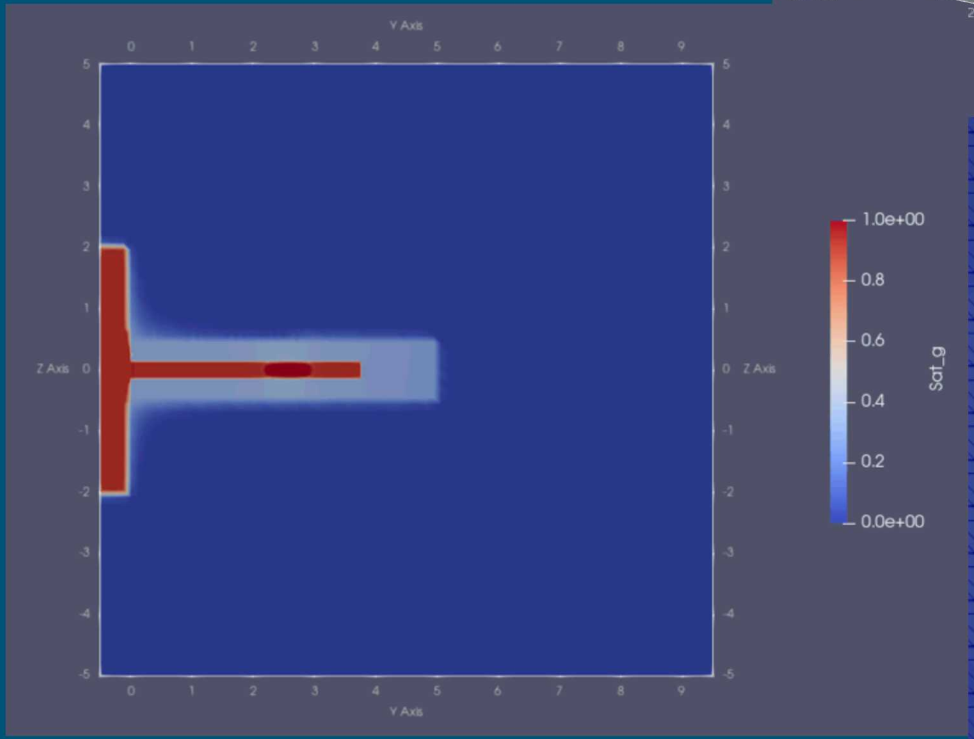
- Well geometry → LaGriT → Voronoi
  - Outputs Voronoi mesh for TOUGH and PFLOTRAN
- 10 m x 10 m x 10 m
  - ~650,000 grid cells
- Include open-air boreholes

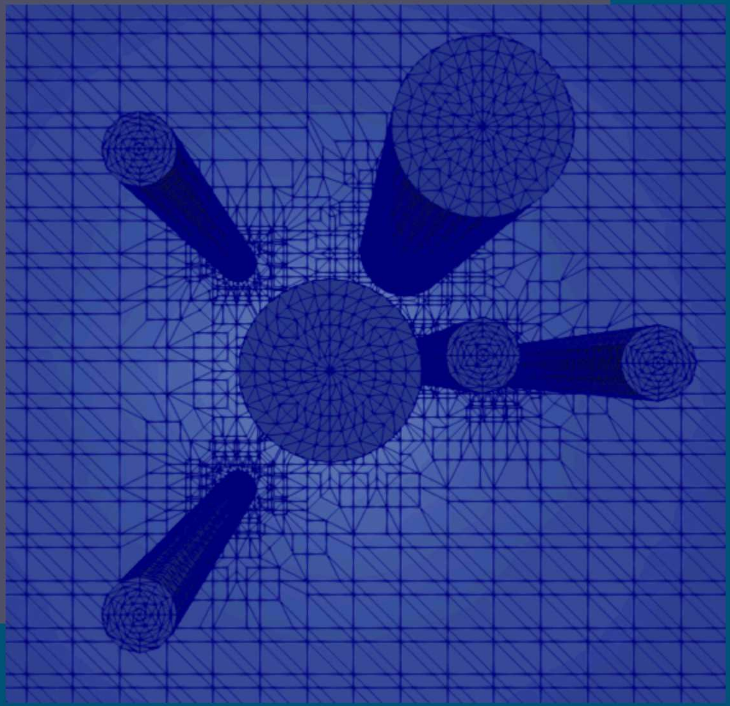
Refinement around wells

VOROCRUST

- Code developed at Sandia
- Voronoi cells
- Test discretization







Future Work

Can we use 1-D models to map the EDZ to incorporate into more complex 3-D models?

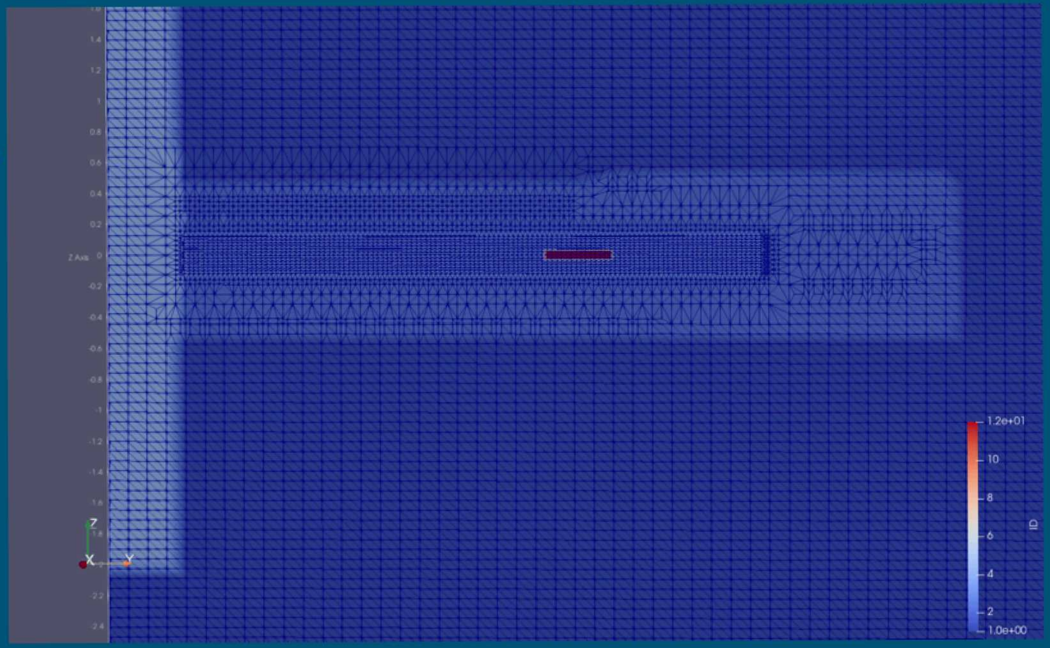
Constrain reservoir parameters via laboratory experiments

- Thermal conductivity vs. temperature
- Heat capacity vs. temperature

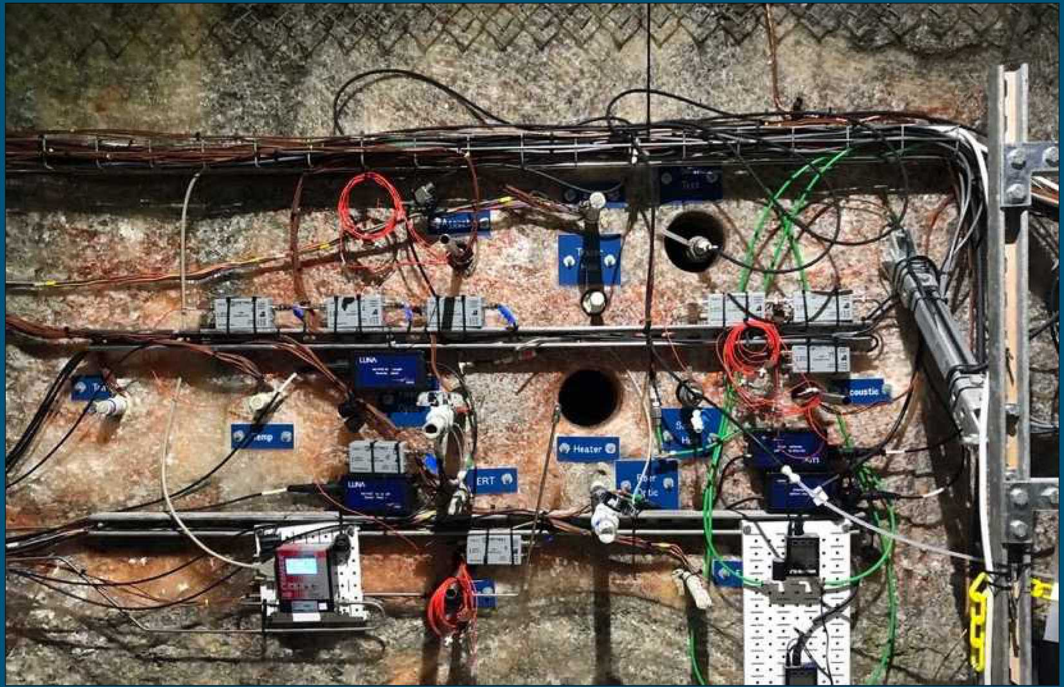
Instead of a distinct separation of the EDZ and intact salt, have reservoir parameters decay as a function of distance from borehole and drift?

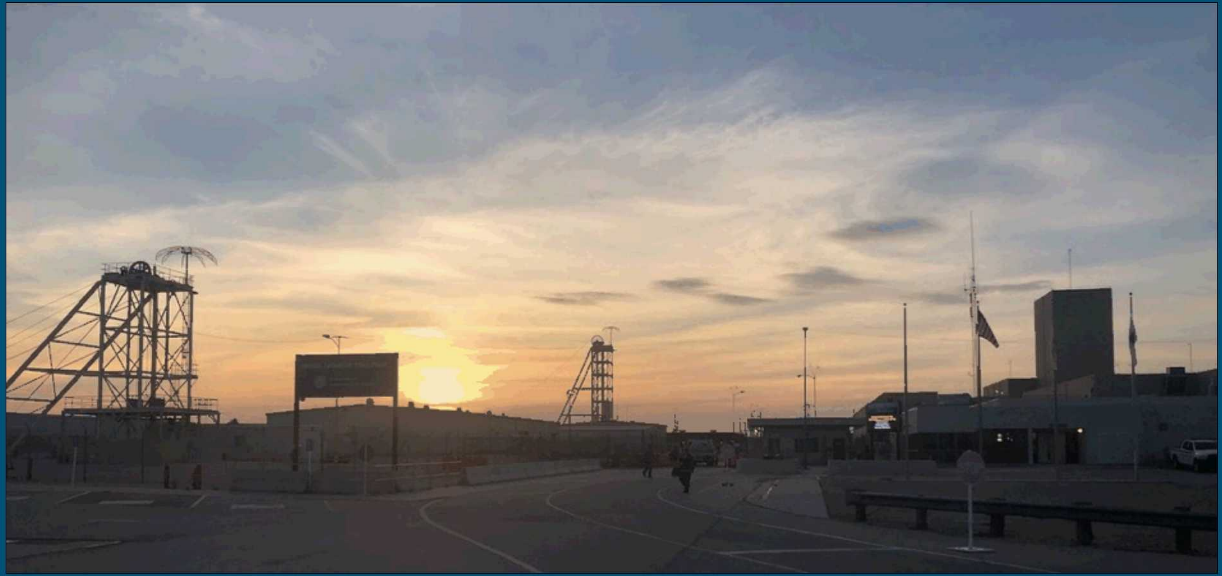
Match brine inflow into borehole.

How to incorporate permeability as a function of temperature?



Thank You!





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