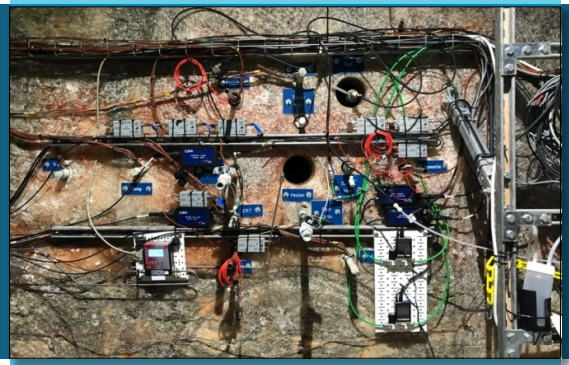
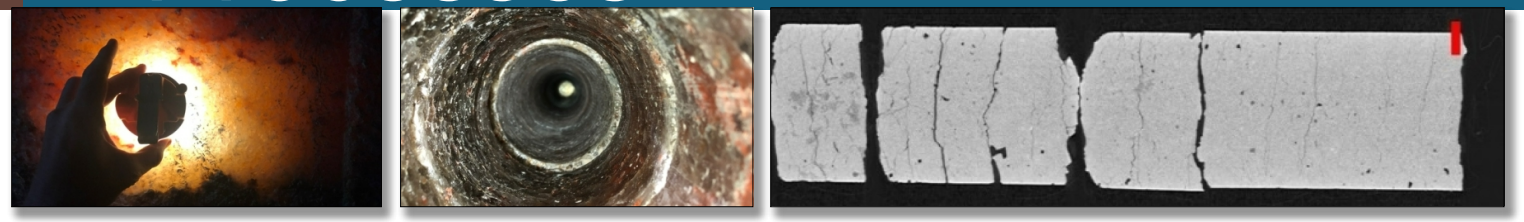
SAND2019-13002C

Sandia National Laboratories

Brine Availability Test in Salt (BATS): Coupled Processes





Kristopher L. Kuhlman

Sandia National Laboratories

DECOVALEX Coupled Processes Symposium, Brugg Switzerland

Tuesday November 5, 2019

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Brine Availability Test in Salt (BATS)

Funded by DOE Office of Nuclear Energy, at Waste Isolation Pilot Plant

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Los Alamos NATIONAL LABORATORY EST. 1943

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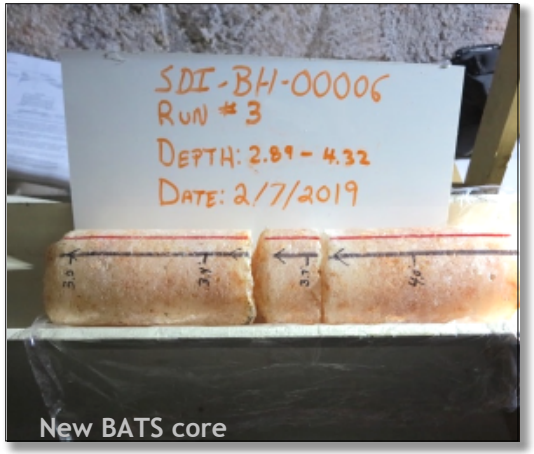
WASTE ISOLATION PILOT PLANT WIPP DOE • LANL • CTAC • SNL

U.S. DEPARTMENT OF ENERGY Office of Nuclear Energy

Focusing on:

hydrologic response as a key to understanding *thermal*, *mechanical*, and *chemical* systems



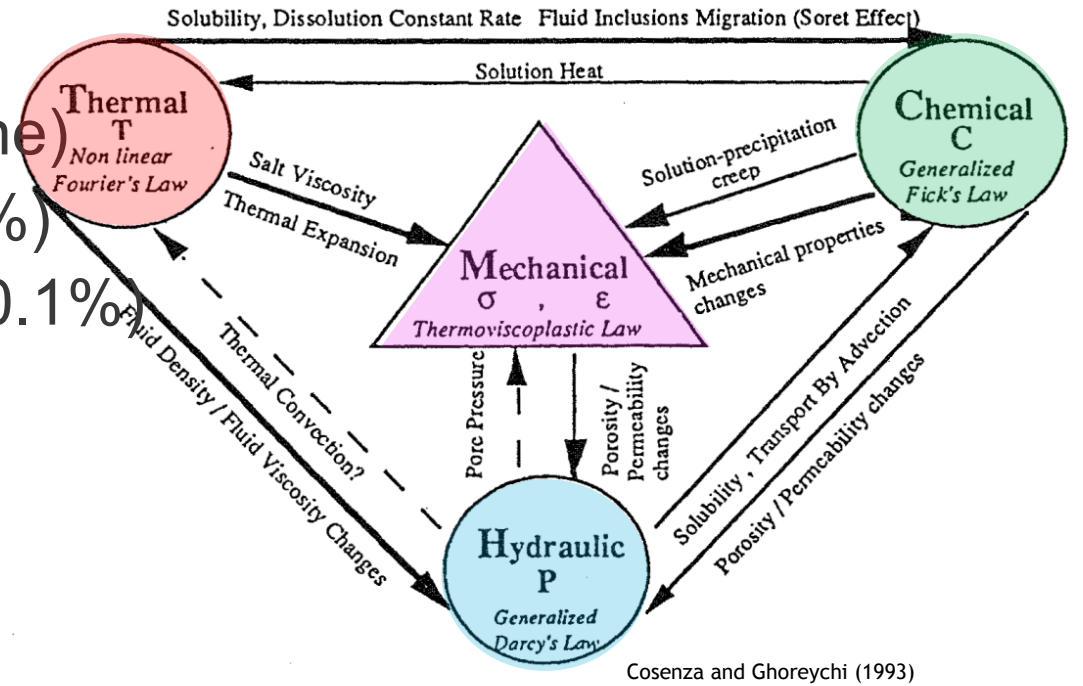
New BATS core


New BATS boreholes


Nearly ready BATS test drift

Why Focus on Brine in Salt?

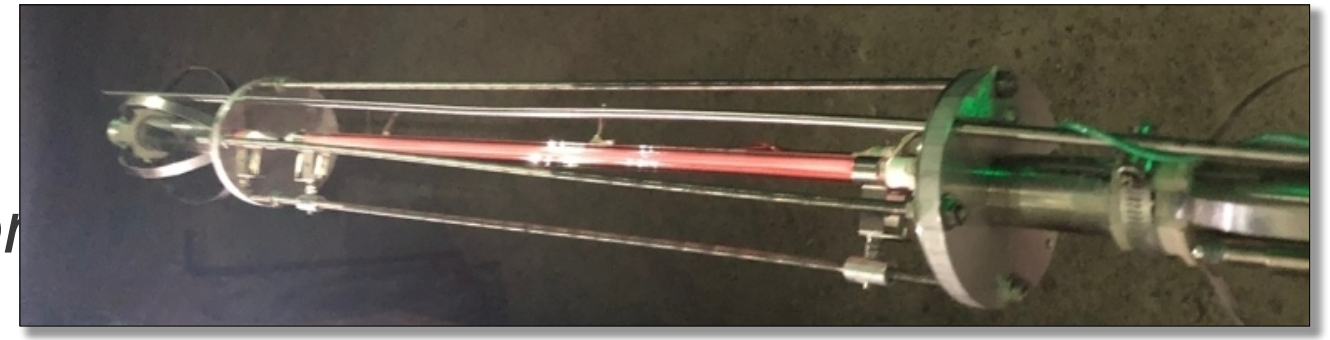
- Water Sources in Salt
  1. Disseminated clay (<5% clay; ~25% brine)
  2. Intragranular brine (fluid inclusions; 1-2%)
  3. Intergranular brine (between crystals; ~0.1%)
- Each Water Type:
  - Respond differently to heat
  - Different chemical / isotopic composition



Cosenza and Ghoreychi (1993)

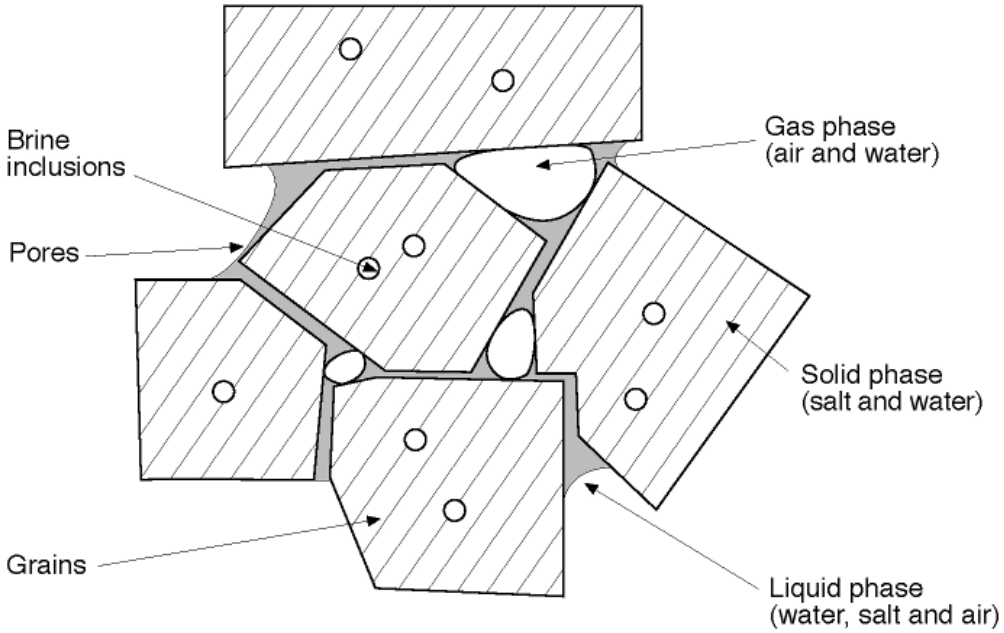
Q: How do 3 Waters Contribute to *Brine Availability?*

- ➢ *How much brine is there?*
- ➢ *How does it get to excavation*

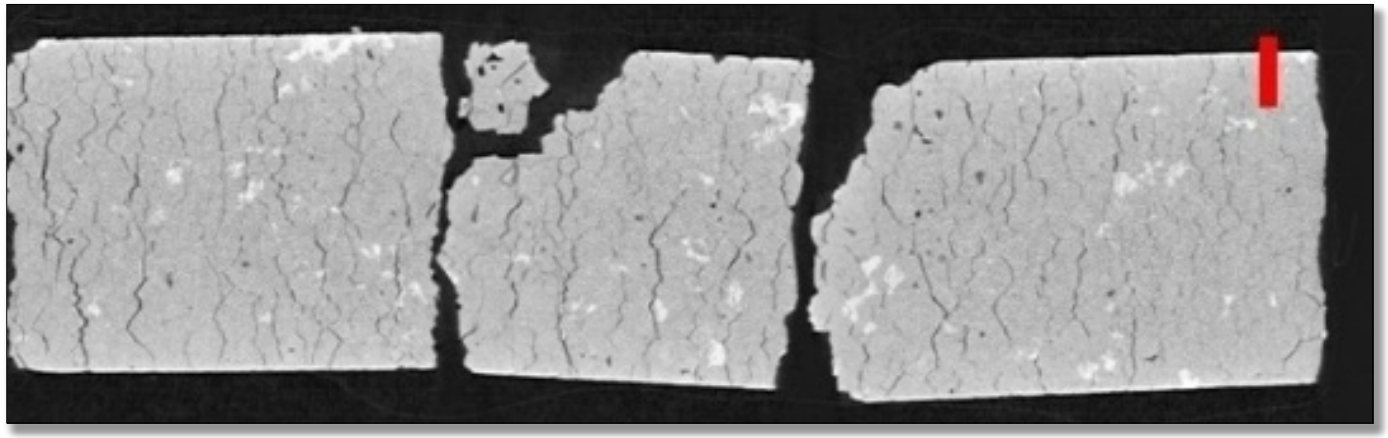


Processes Coupled Through Porosity

- Damage **Creates** a Flow System
- Porosity Evolves:
  - Precipitation / dissolution
  - Mechanical damage / healing
  - Hydrofracture
- Processes Depending on Porosity
  - Advection of liquid / gas
  - Heat convection (free / forced)
  - Reactive transport
- Depend Less on Porosity
  - Heat conduction
  - Mechanical deformation

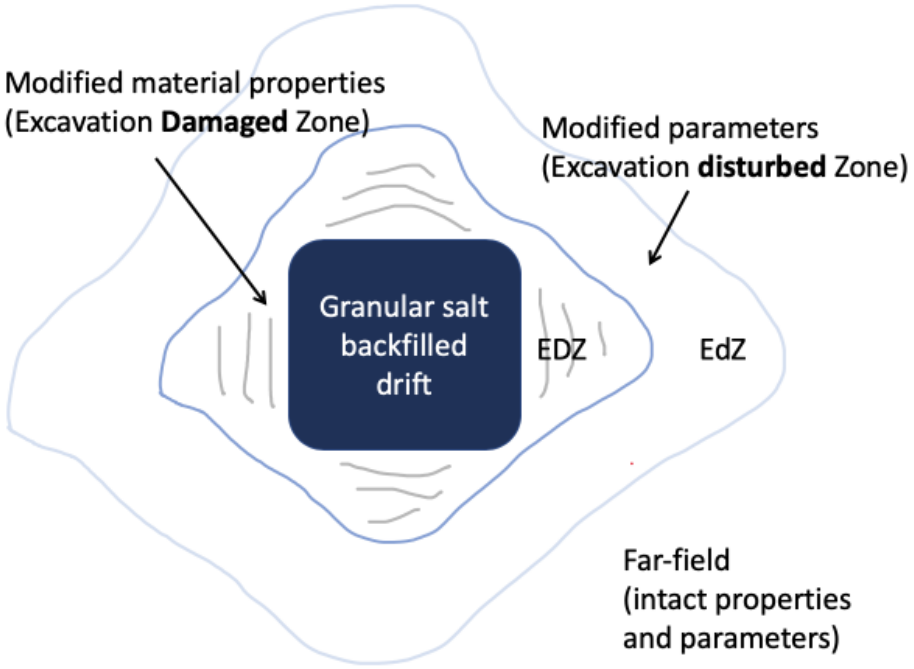


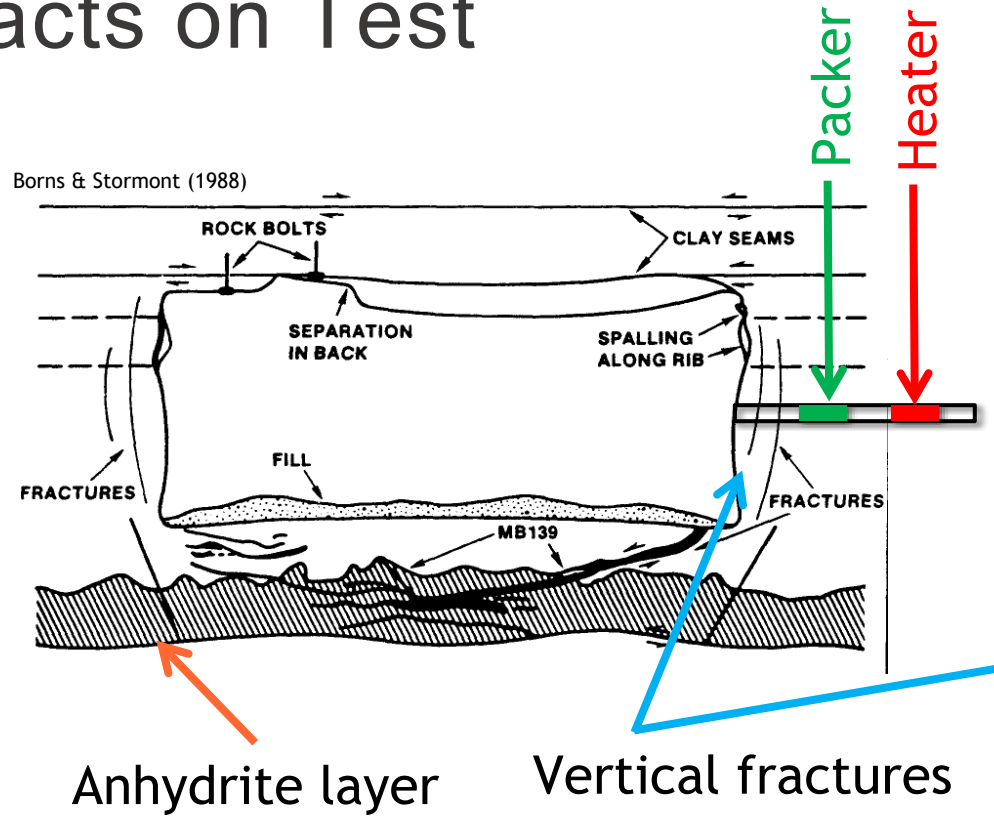
20 mm scale bar



X-Ray CT scan of core from BATS

Damaged Zone Impacts on Test





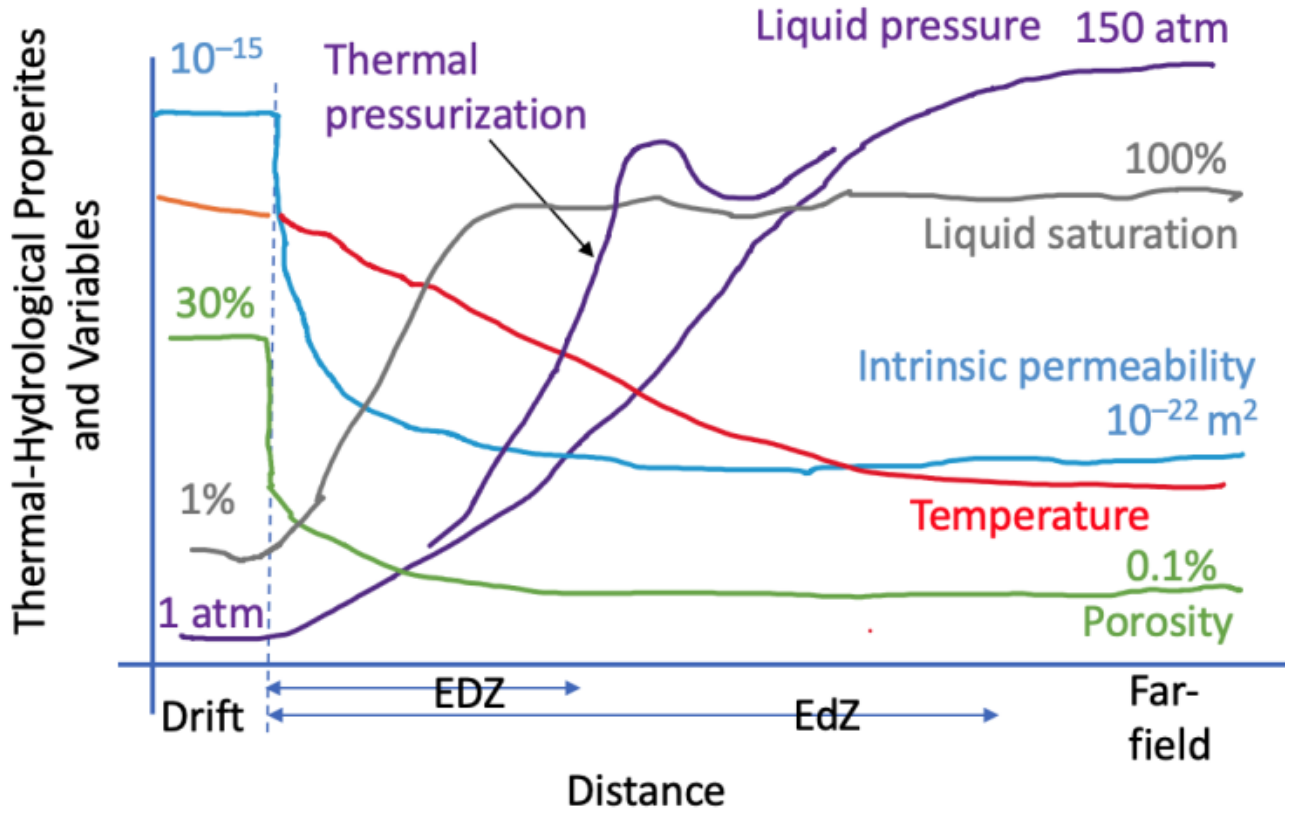
BATS borehole

Characterize EDZ while avoiding most damaged areas

- *Horizontal borehole* avoids layers in floor
- *Inflatable packer* isolates from near-drift vertical fractures

Hydrologic System as Mechanical Indicator / Driver

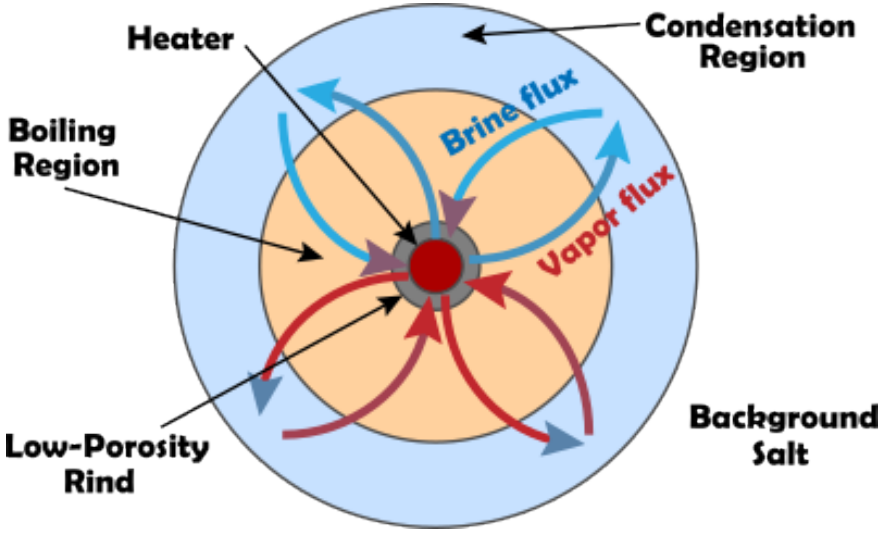
- Hydrologic Properties / Variables
  - ***Huge*** gradient across EDZ
  - In-drift
    - Low pressure
    - High porosity & permeability
    - Gas filled porosity
  - Far-field
    - High pressure
    - Low porosity & permeability
    - Brine filled porosity
- Thermal pressurization
  - Thermal diffusivity ≥ hydraulic diffusivity

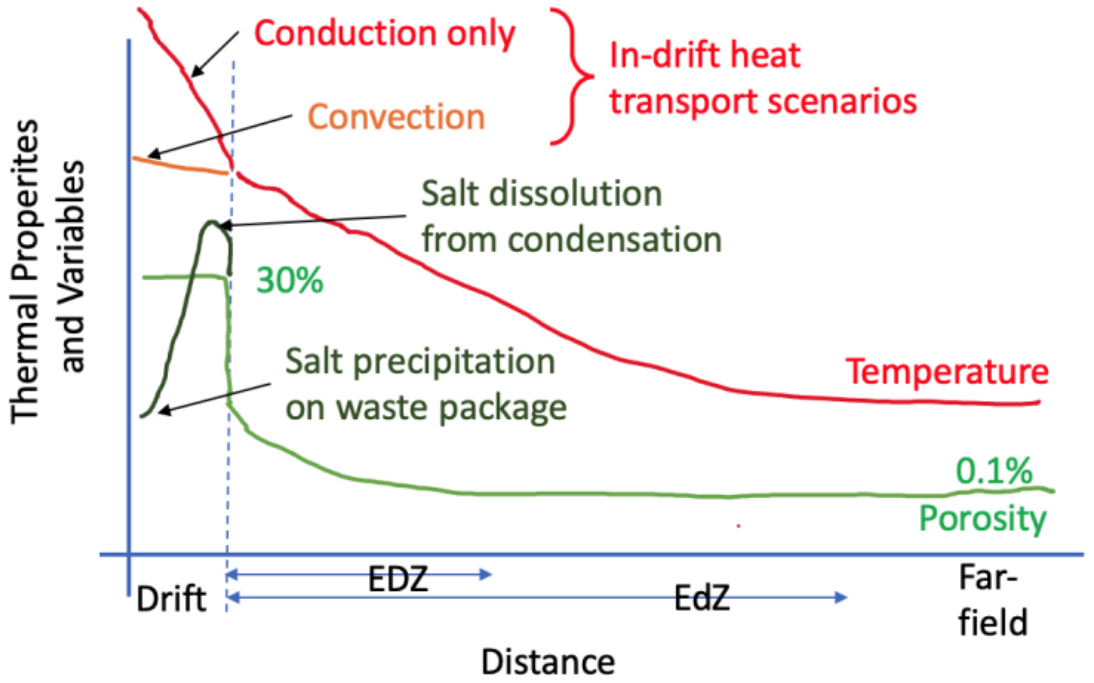


EDZ/EdZ eventually shrink

Water as Energy Indicator / Redistributor

- Hot Waste Packages (≫1 kW)
- Hot = More brine available
  - Liberate fluid inclusions
  - Dry out hydrous minerals (e.g., gypsum)
  - Dry out clay
- Establish a Heat Pipe?
  - Free convection
  - Requires high porosity
  - Requires very hot source
  - Lowers peak temperature at waste
- Dry Out Near Field?
  - Dry salt is less corrosive

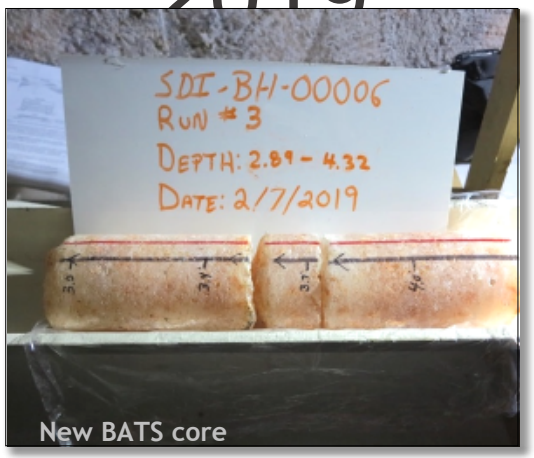




Brine Availability Test in Salt (BATS)

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

Test implemented by Oct 2019, heating begins late 2019



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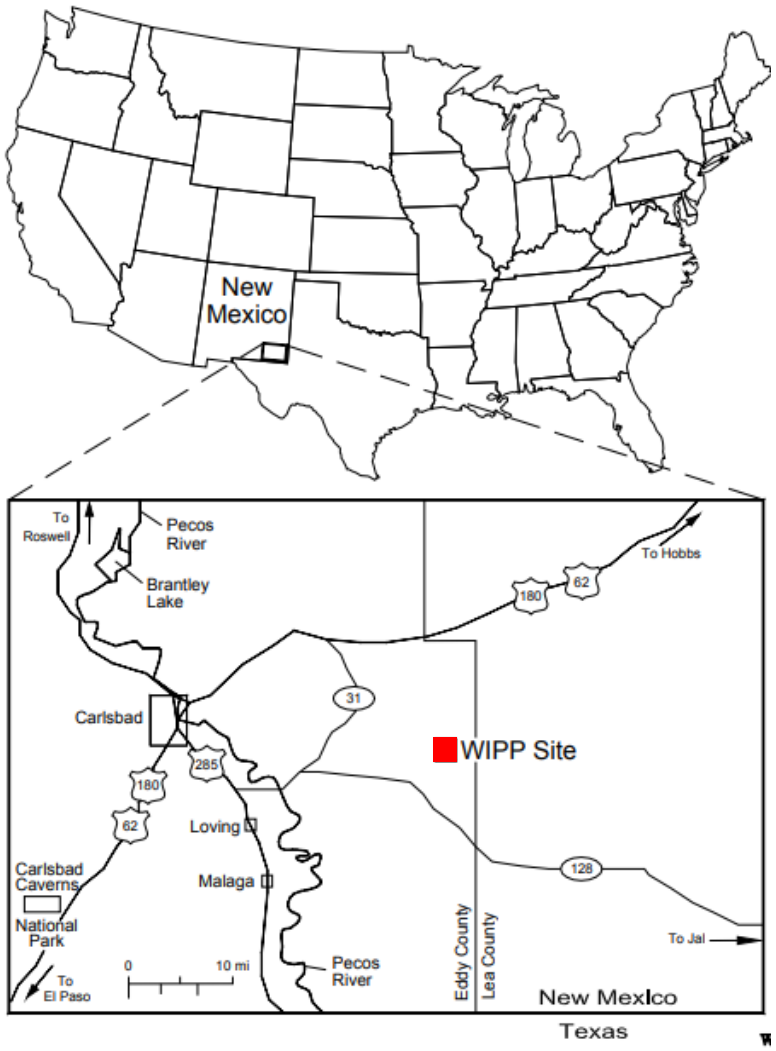
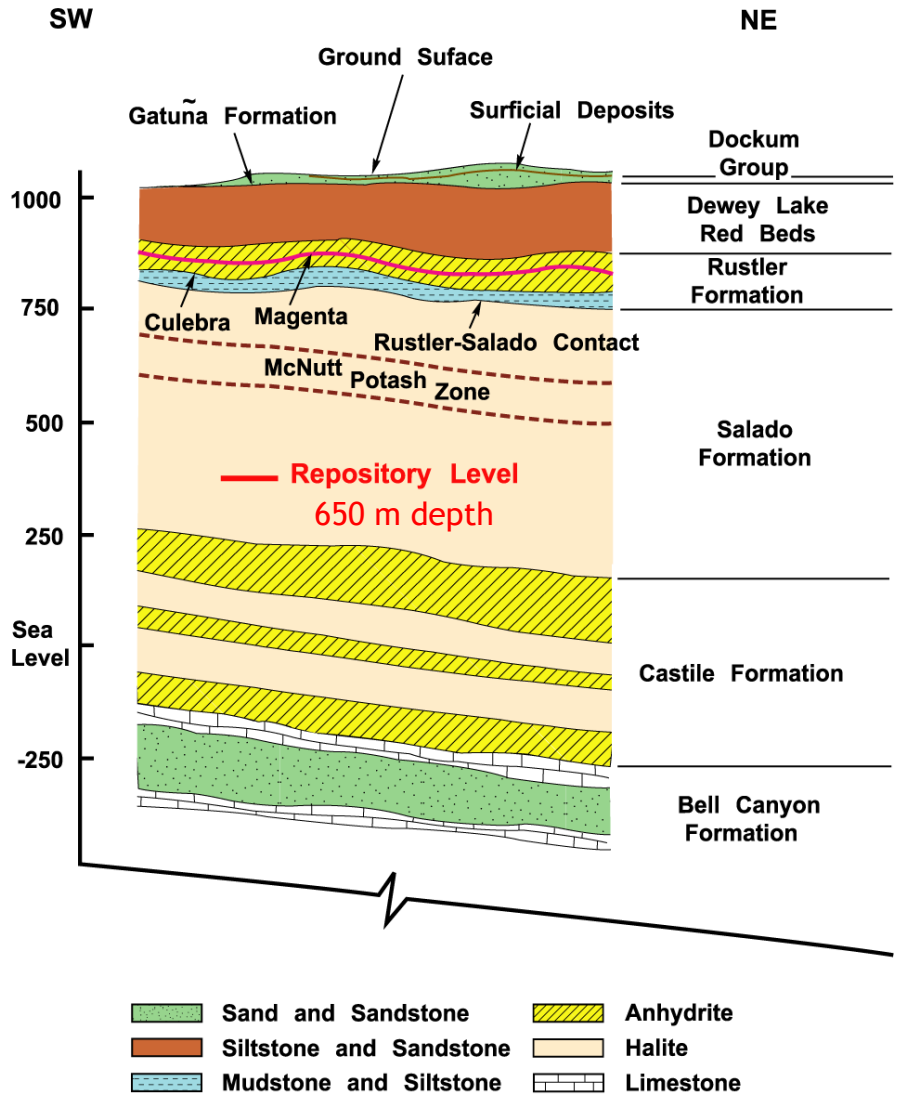
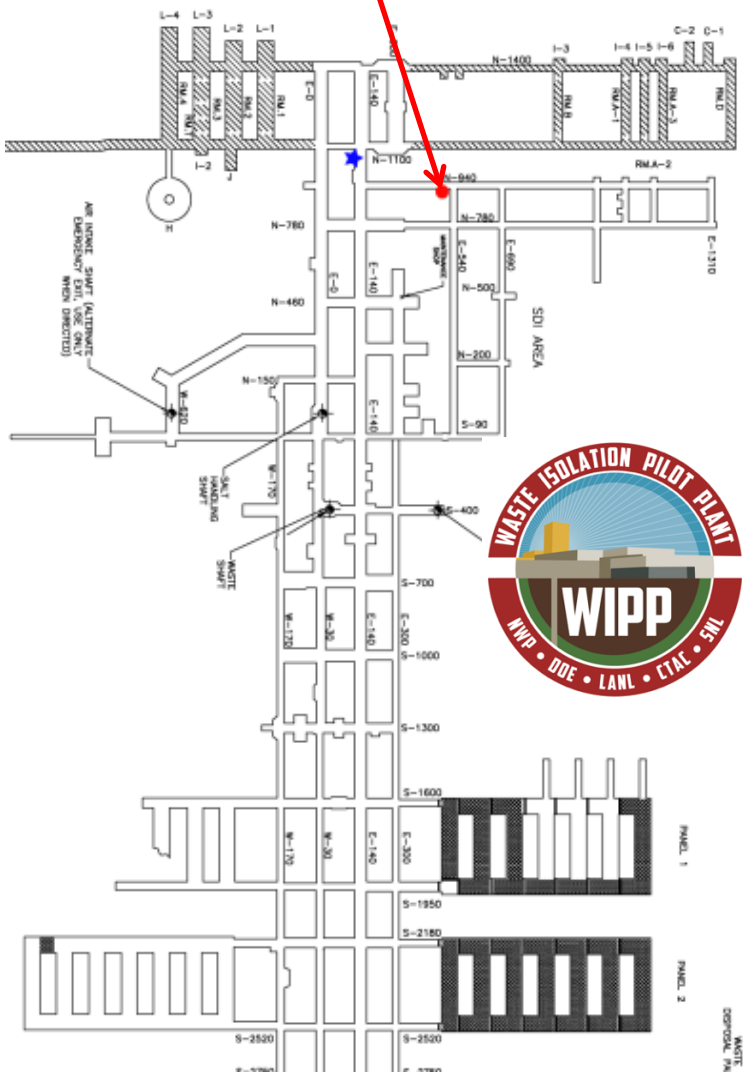
Waste Isolation Pilot Plant

U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

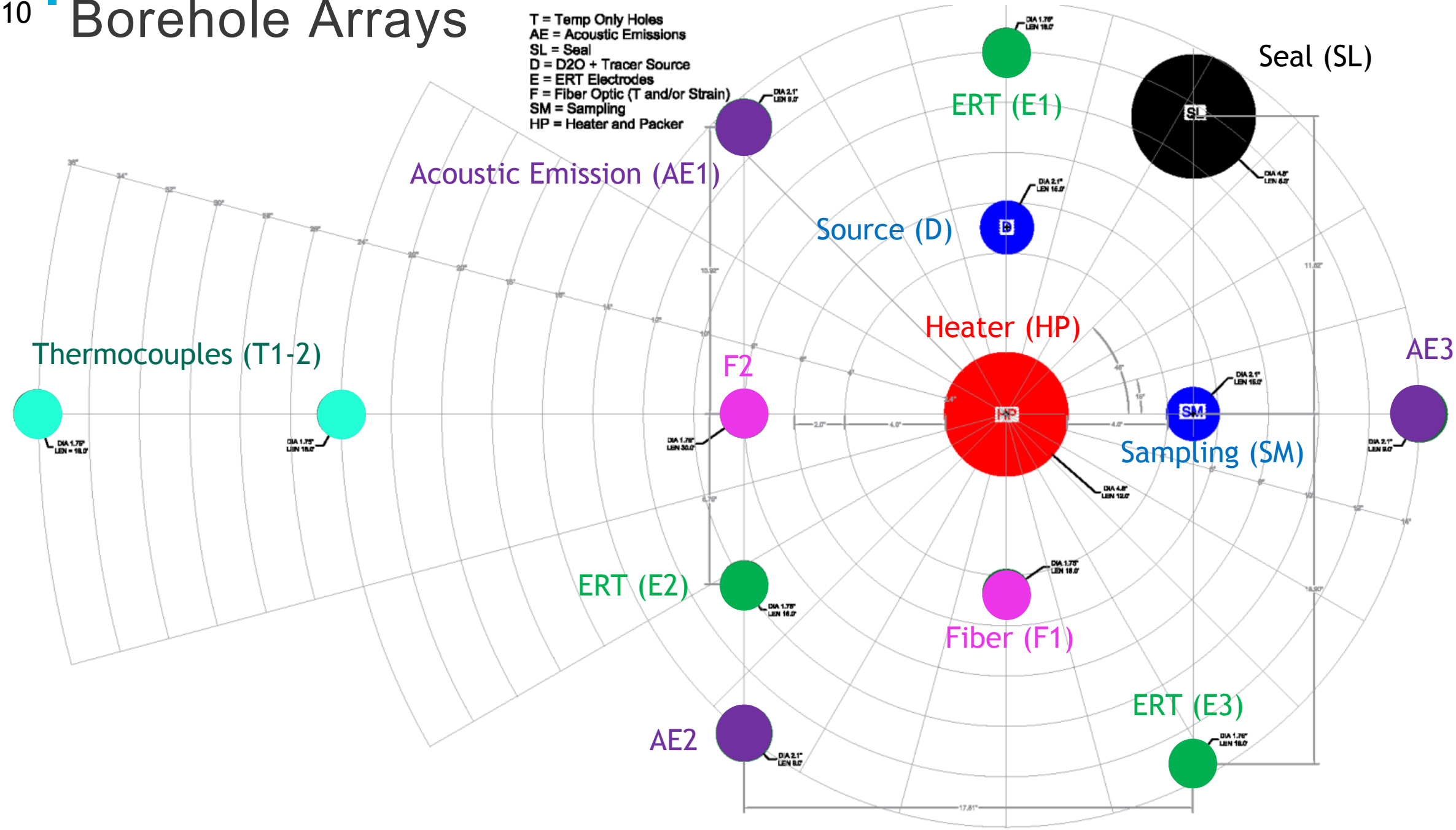




BATS test location
Mined 2012

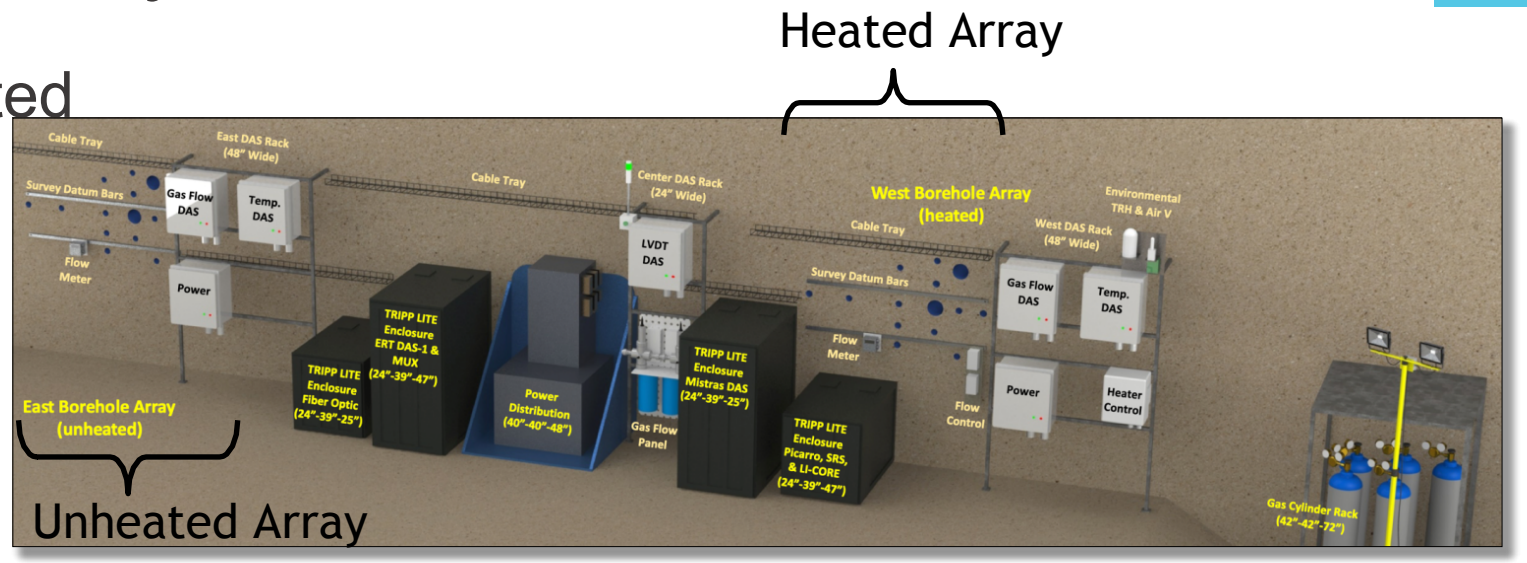


Borehole Arrays



Data Collection Summary

Two Arrays: Heated / Unheated



Behind packer

- Circulate dry N_2 gas
- Quartz lamp heater (750 W)
- Borehole closure gage

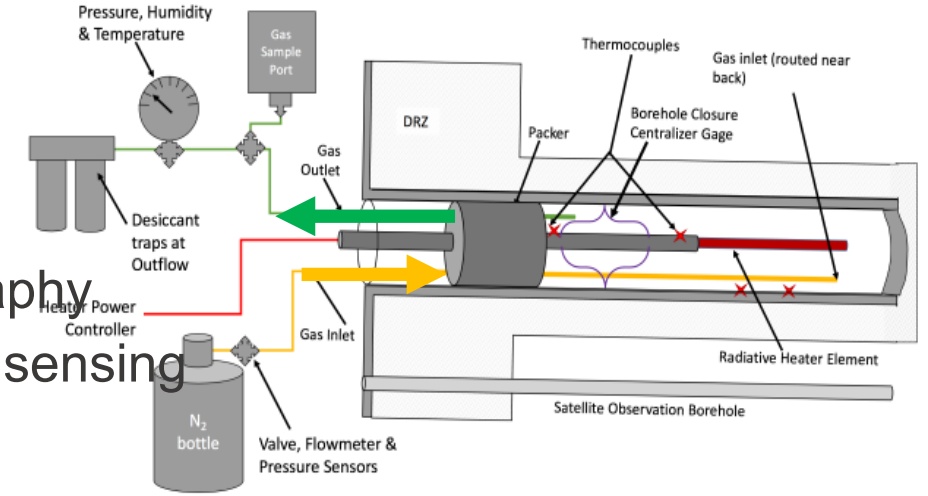
Samples / Analyses

- Analyze gas stream (natural / applied tracers and isotopic makeup)
- Collect liquid brine (natural chemistry and natural / applied tracers)
- Collect cores (X-ray CT and fluorescence at NETL)

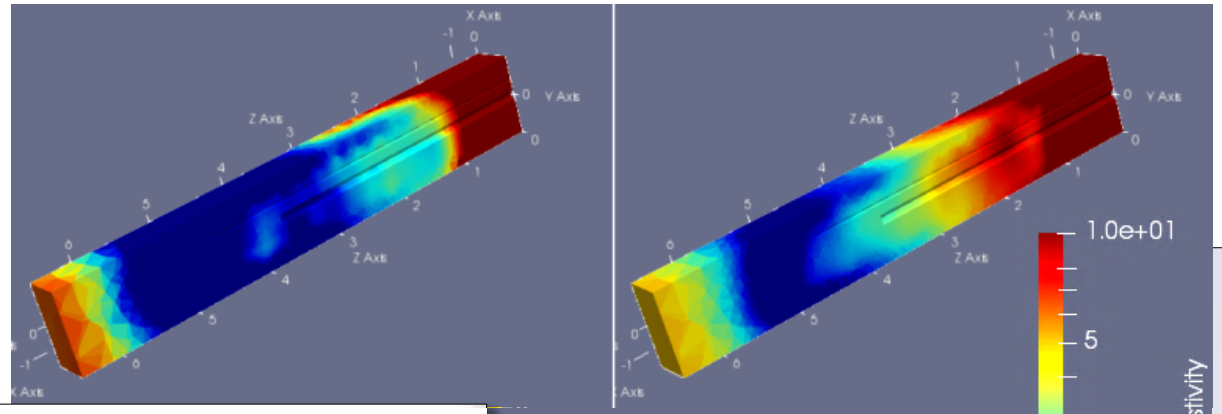
Geophysics

- 3× Electrical resistivity tomography (ERT)
- 3× Acoustic emissions (AE) / ultrasonic travel-time tomography
- 2× Fiber optic distributed strain (DSS) / temperature (DTS) sensing

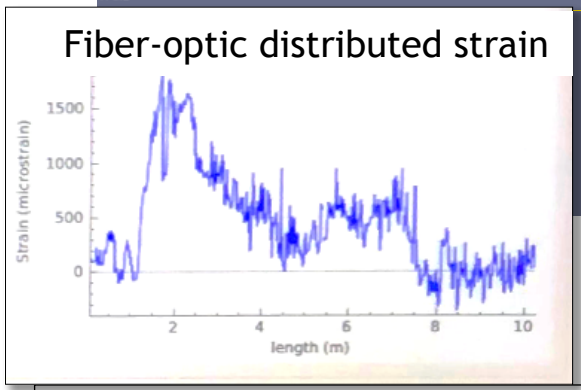
Cross-section central borehole

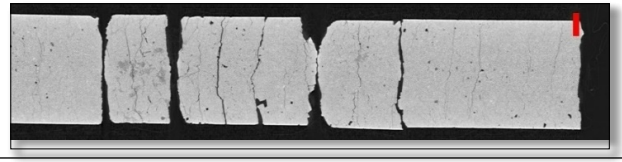


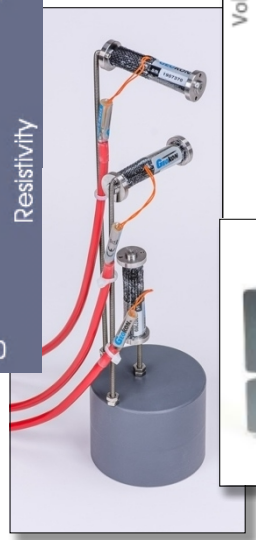
Historic and Preliminary Data

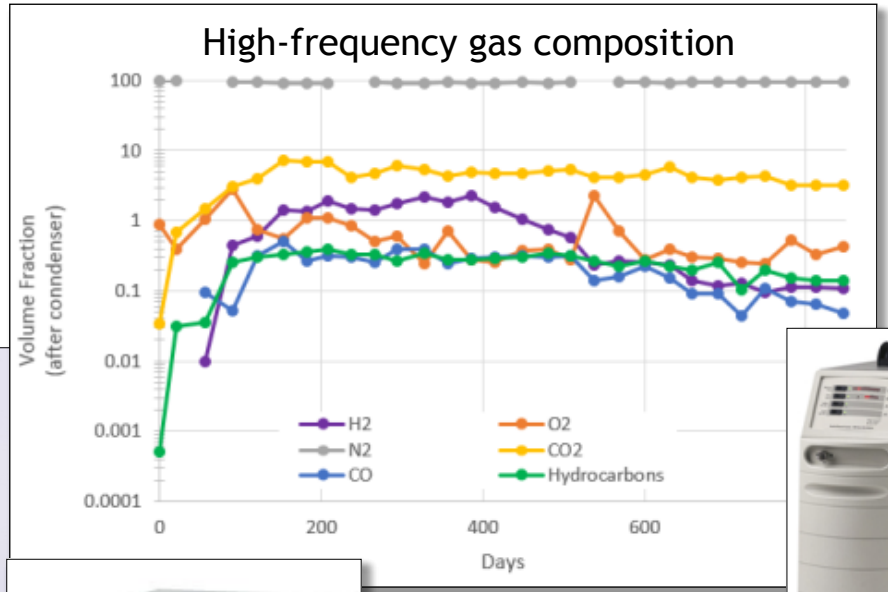


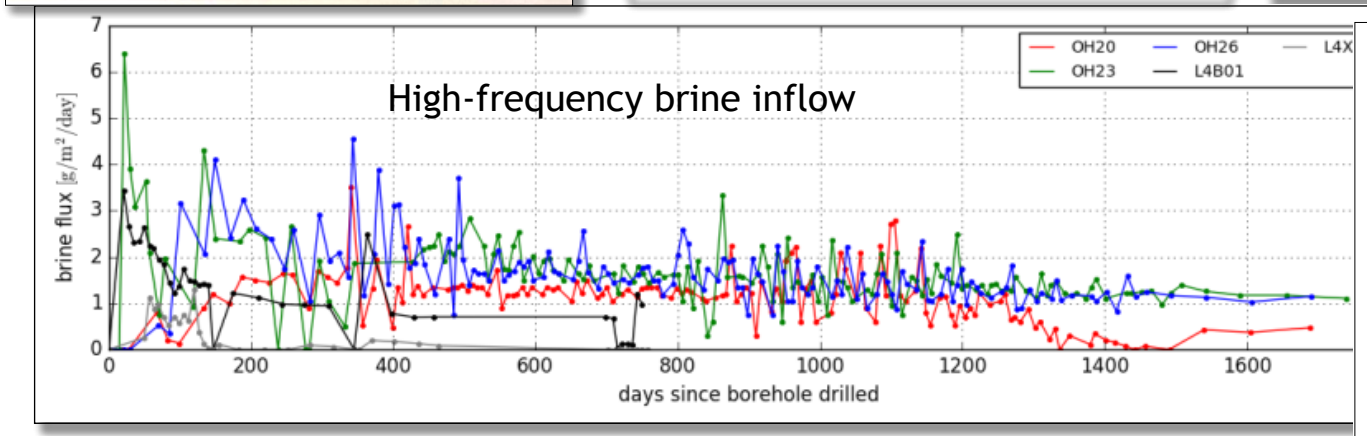
Electrical resistivity tomography

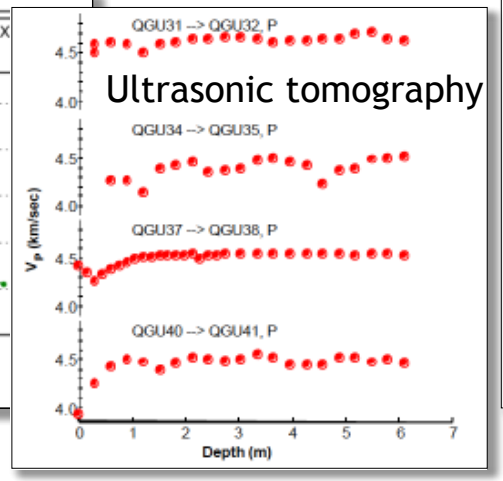


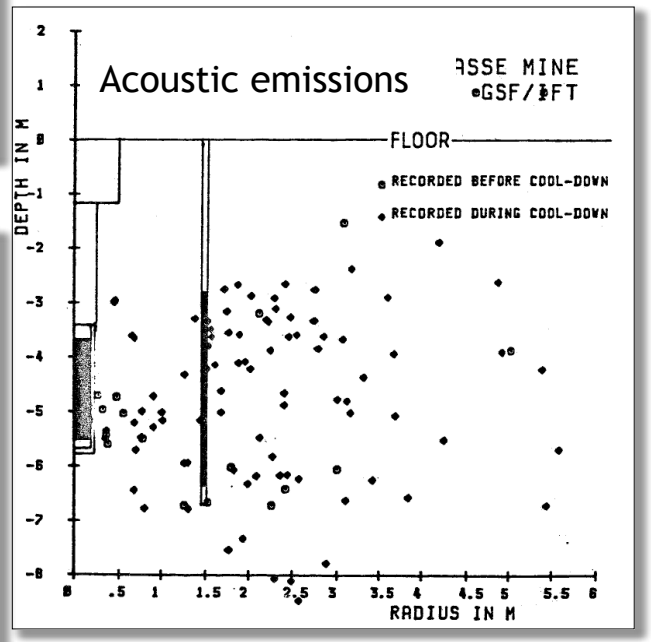












Why are These Data Useful?

Brine composition samples / H_2O isotope data

- Change in brine types with temperature

Geophysics

- Map 4D evolution of saturation / porosity

Temperature Distribution

- More brine at high temp (inclusions + hydrous minerals)
- Thermal pressurization
- Salt dry-out near borehole

Gas Permeability and Borehole Closure

- THM evolution of salt during heating

Gas / Liquid Tracer Migration

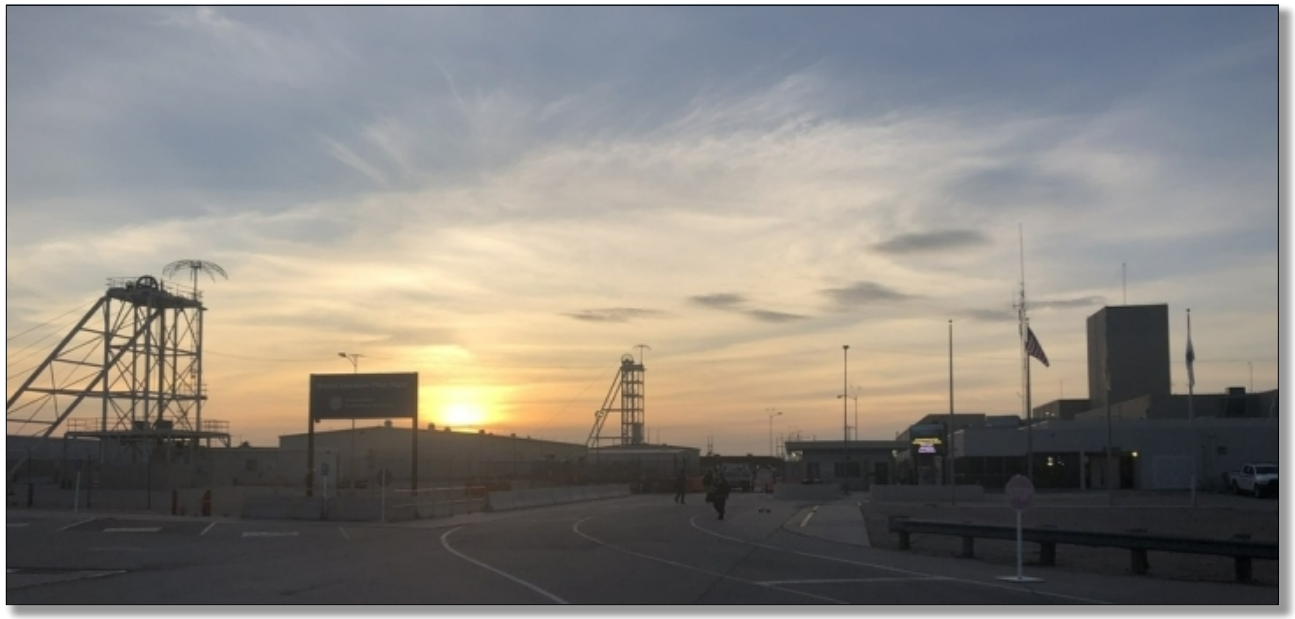
- Advection / diffusion / reaction

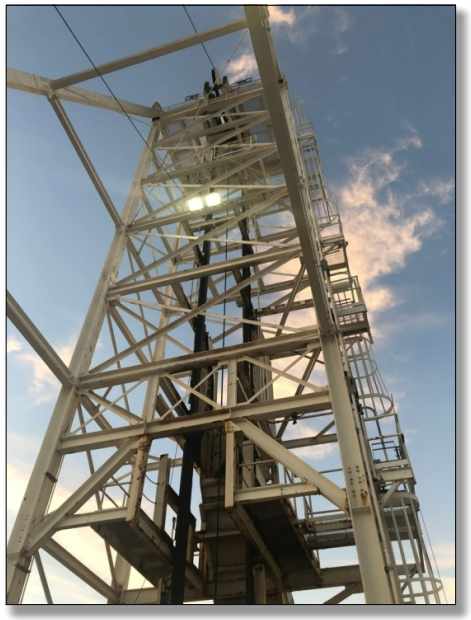
How to Interpret Data?

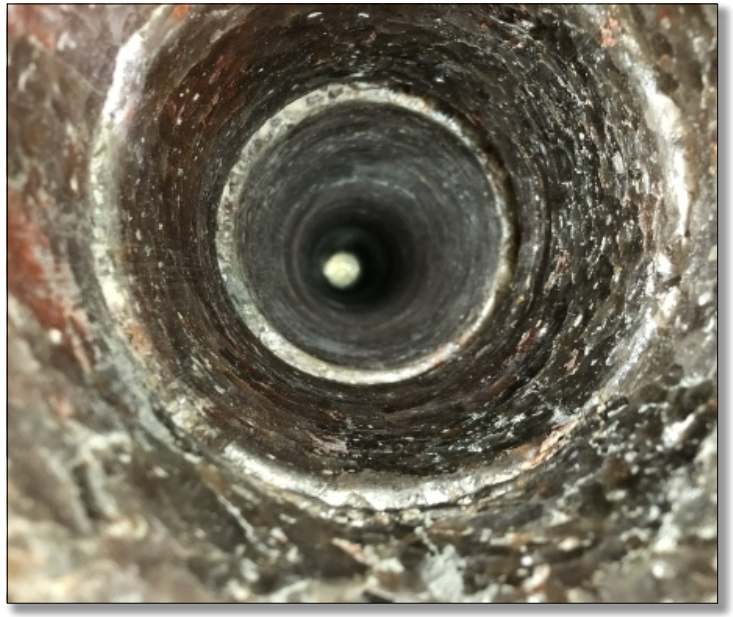
1. Thermal (T) response (i.e., conduction)
2. Two-phase Hydrologic (H) unheated response (i.e., diffusion)
3. Thermal-Hydrologic (TH) response (+ convection)
   - Dry-out
4. TH-Mechanical (THM) response of salt
   - Fiber-optic strain & borehole closure
   - AE response of salt (damage = new permeability)
5. TH-Chemical (THC) response of salt
   - Contribution of each brine type
   - Prediction of precipitated phases

Do we need a Discrete Fracture Network? (Salt is "crystalline" rock)

Thank you!







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