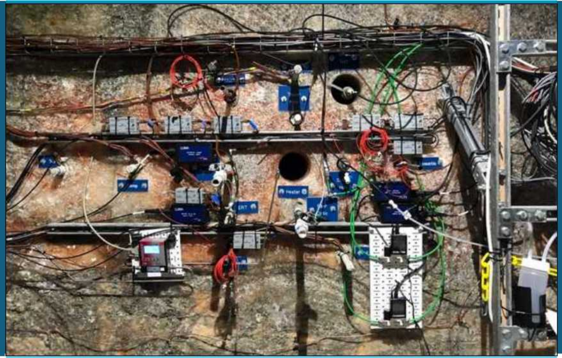
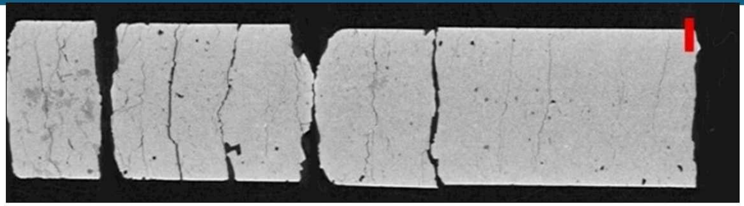
SAND2019-12806PE

Brine Availability Test in Salt (BATS)





Kris Kuhlman

Sandia National Laboratories

DECOVALEX Meeting, Nov 2019

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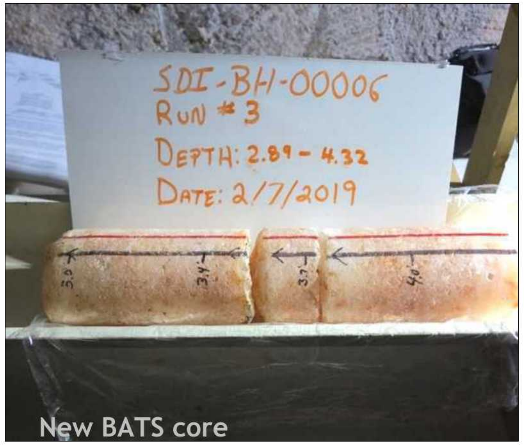
SAND2019-12447 PE

What Are We Doing?

Brine Availability Test in Salt (BATS)

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

Boreholes drilled (Feb-April), instrumentation installed (Aug-Sept), test began Oct



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% total; ~25 vol-% brine)
  2. Intragranular brine (fluid inclusions; 1 to 2 vol-%)
  3. Intergranular brine (between salt crystals; ~0.1%)

- Three types of water
  - Respond differently to heat
  - Different chemical / isotopic composition

- Salt damage → primary flow path

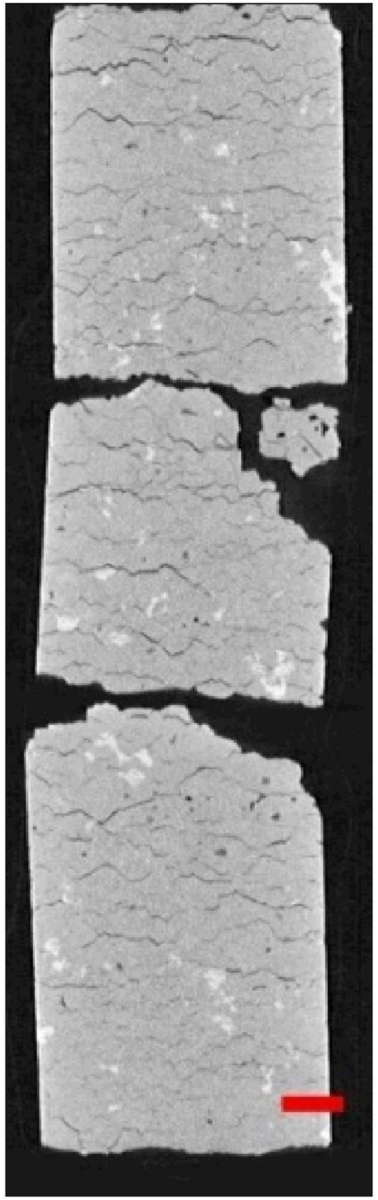
Q: How do 3 water types contribute to *Brine Availability?*

✓ *How much brine?*

✓ *How does it flow to excavation?*

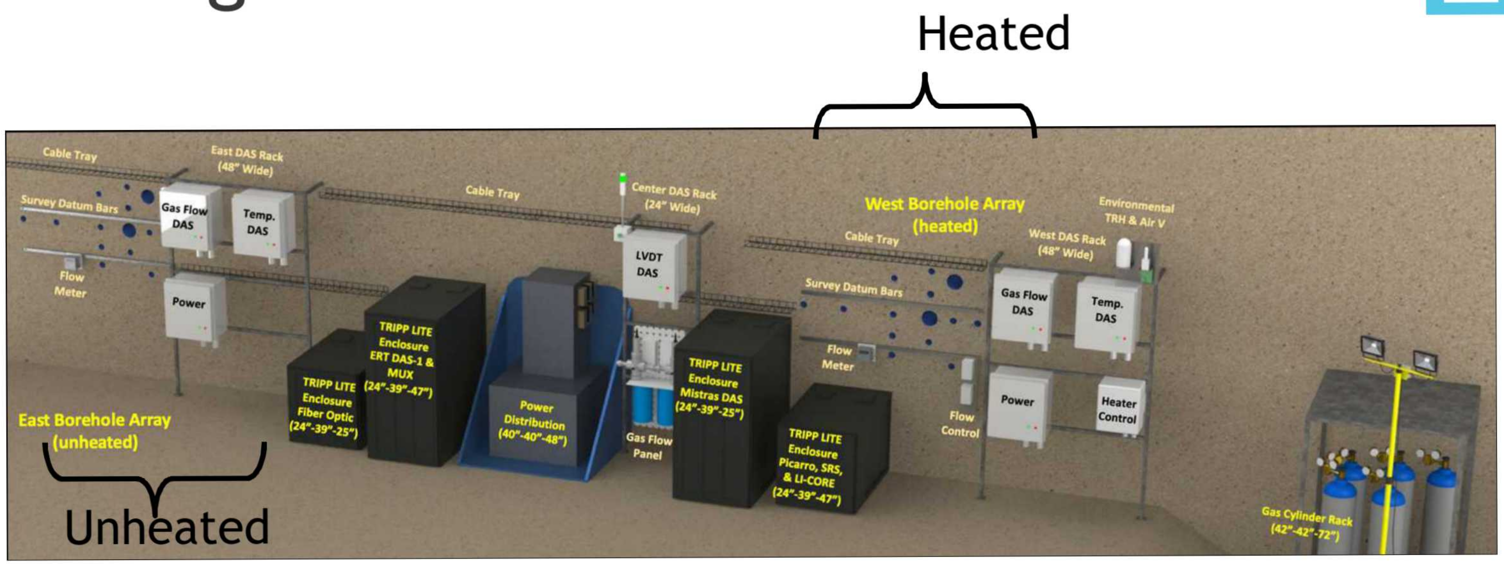
Fluid inclusions

2 mm scale bar



20 mm scale bar

What Data are We Collecting?



Two arrays: heated / unheated

Behind packer

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

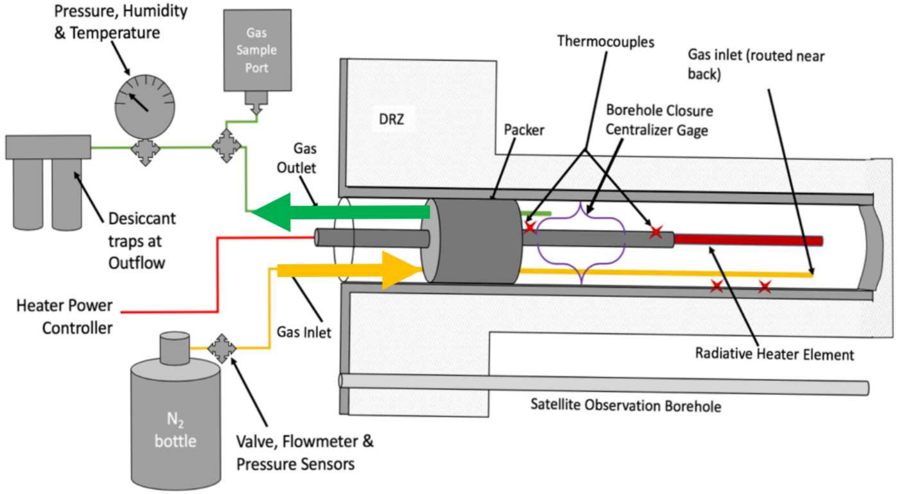
Samples / analyses

- 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)

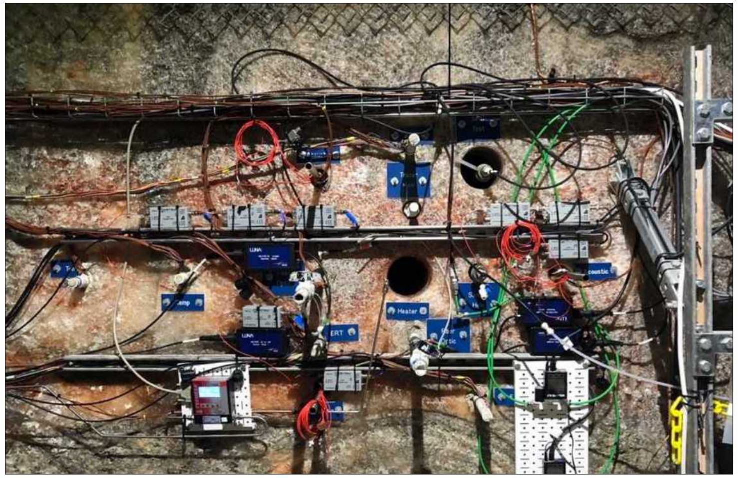
Geophysics

- 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



Why are These Data Useful?



Brine composition samples / H_2O isotope data

- Observe change in brine sources with temperature

Geophysics

- Map 4D evolution of **saturation** / **porosity** / **permeability**

Temperature distribution

- More brine available at high temp (inclusions + hydrous minerals)
- Thermal expansion brine driving force
- Salt dry-out near borehole

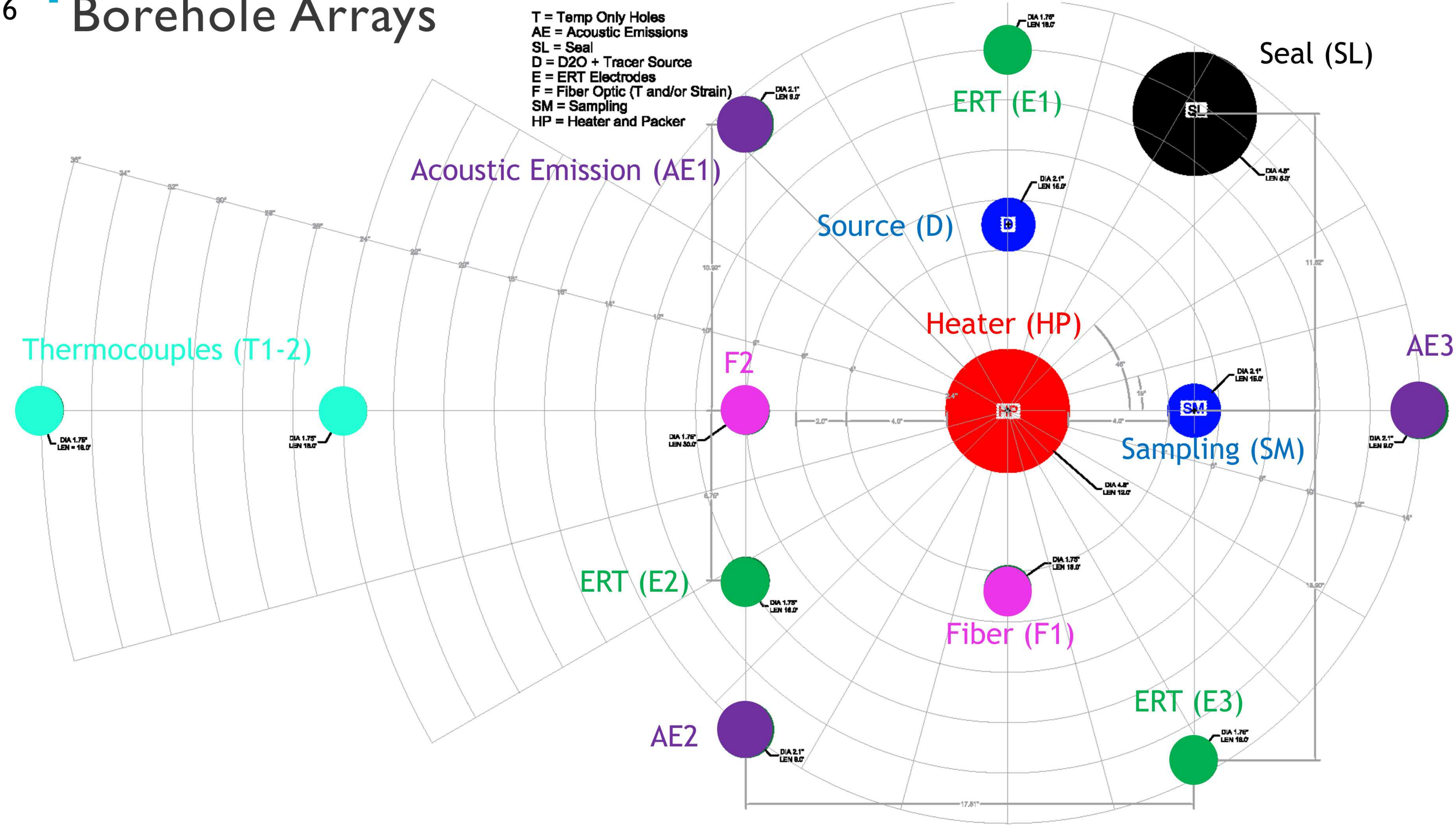
Gas permeability and borehole closure

- Thermal-hydrological-mechanical evolution of salt during heating

Tracer migration through salt

- Monitor brine movement through salt damage zone

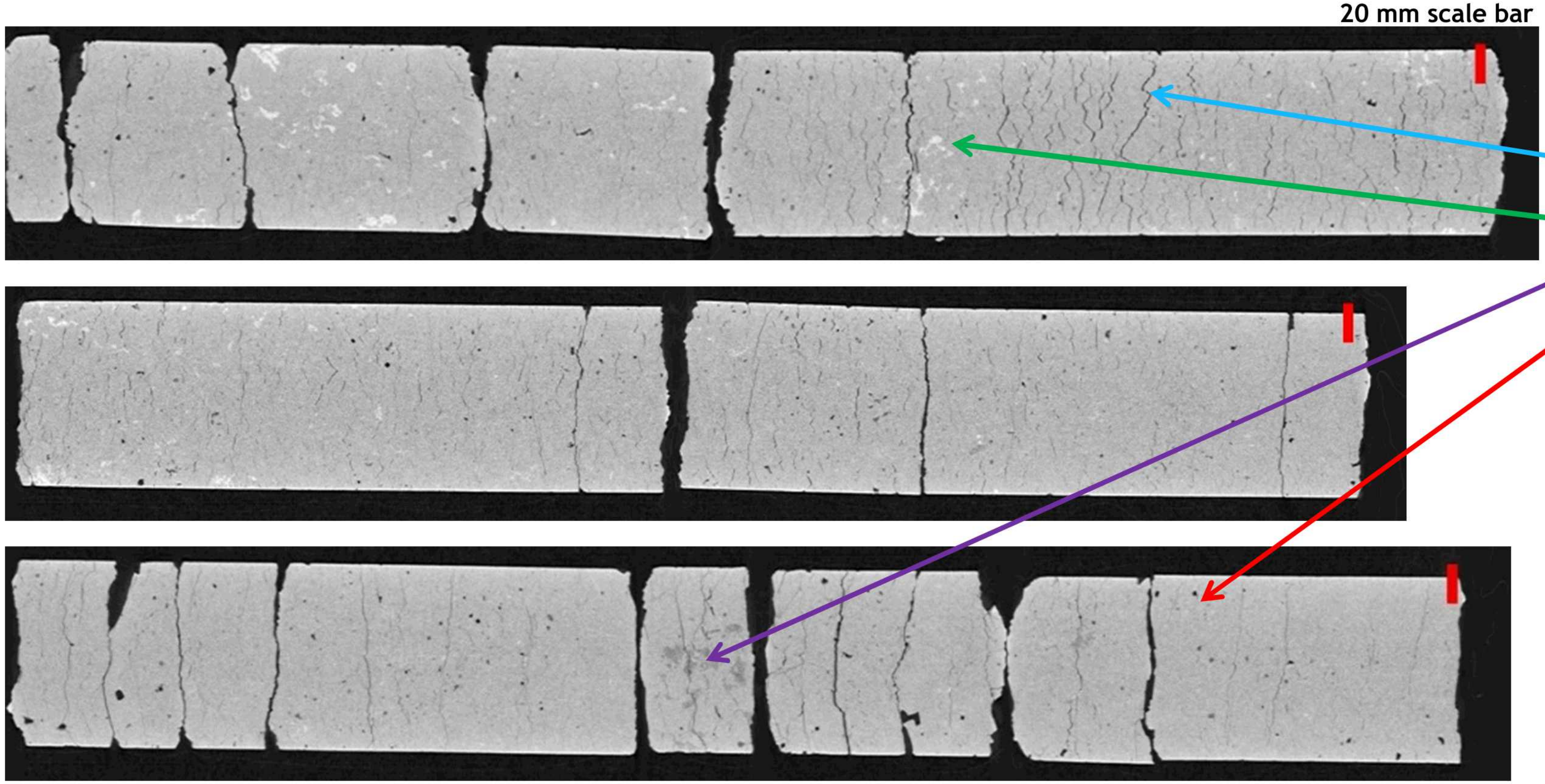
Borehole Arrays



Site Characterization Data

Cores from 4.8” boreholes

- X-Ray Computed Tomography (CT)
- X-Rat fluorescence (XRF)

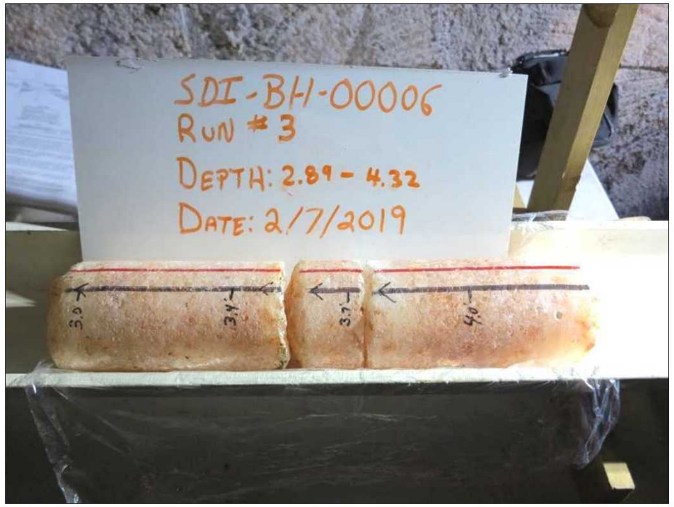


Distribution in 3D:

Fracture porosity

Clay & polyhalite

Fluid inclusions



Imaging by Dustin Crandall at National Energy Technology Laboratory (NETL)

Brine Inflow

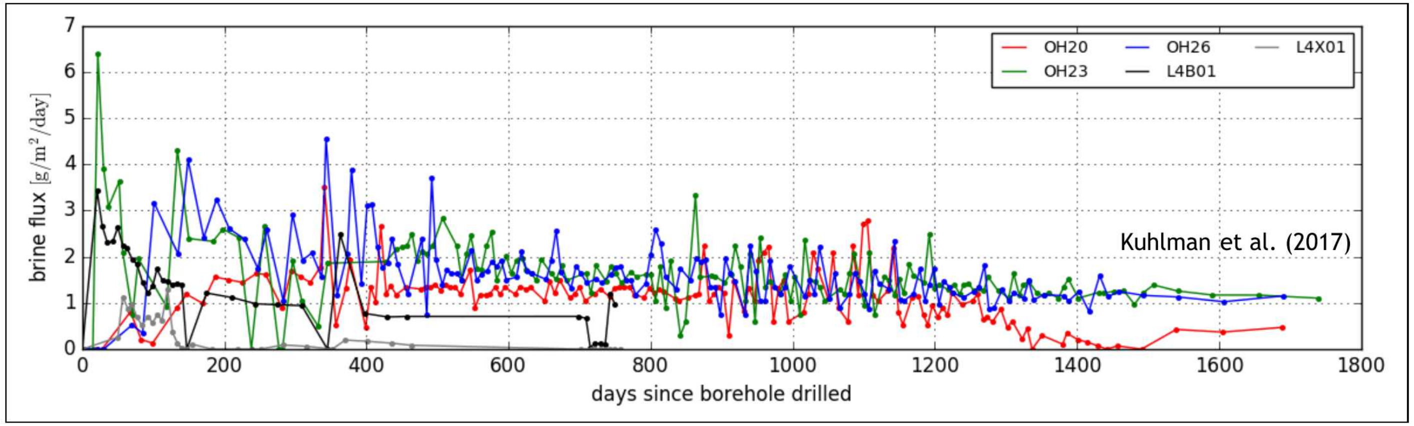
Gas flowrate + humidity

Brine inflow to boreholes

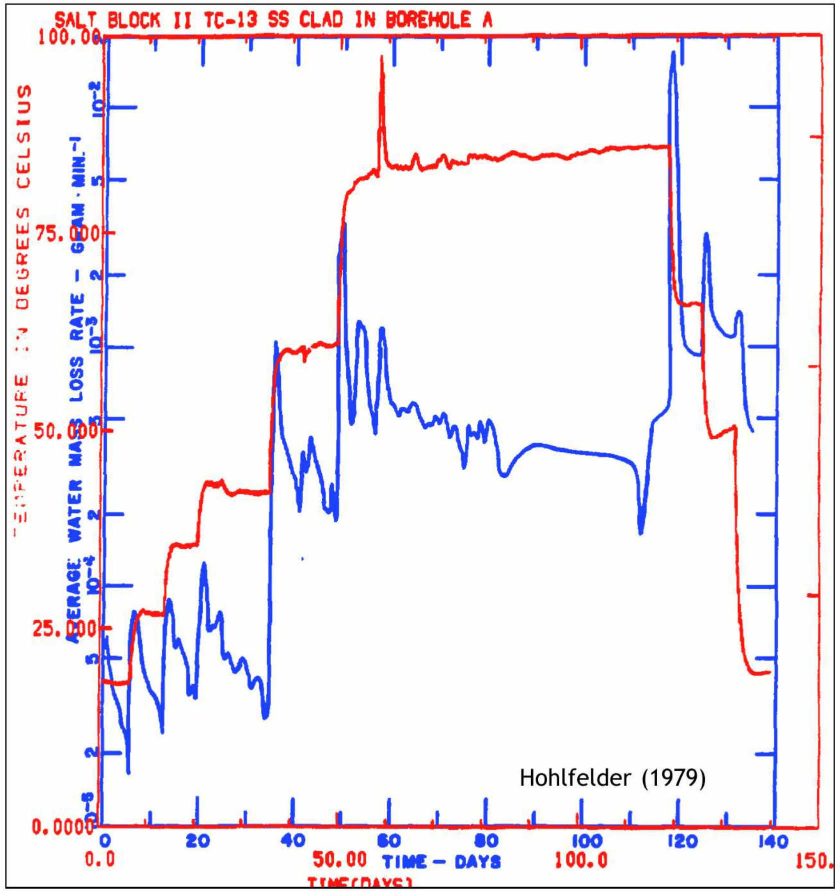
- Highest inflow rate initially
- Rate exponentially decays with time

Brine inflow jumps at $\pm\Delta T$

Permeability / brine saturation of salt



1990s horizontal borehole brine inflow at WIPP



Salt Block II (1-m lab test)

Gas Stream Composition

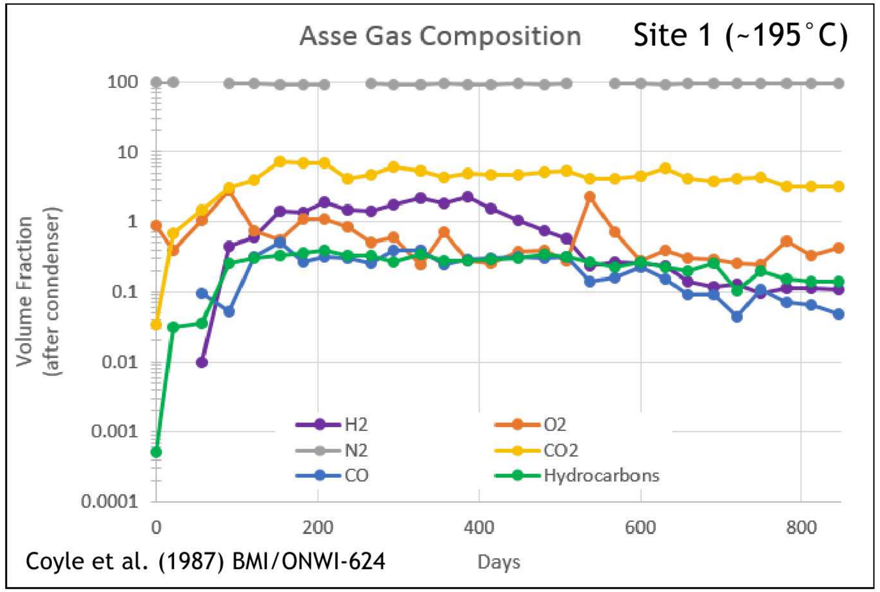
<u>Analyze gas stream in-drift real-time</u>

Gases derived from

- Dissolved gas in brine (~15 MPa in far field)
- Geogenic gases from salt (e.g., He & Ar)
- Added gas tracers (Xe, Ne, Kr & SF_6)

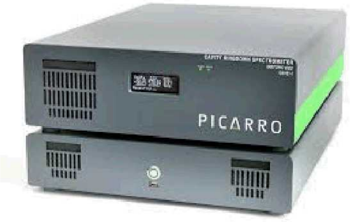
Isotopic makeup of humidity stream

Quadrupole mass spectrometer (QMS) gas analyzer

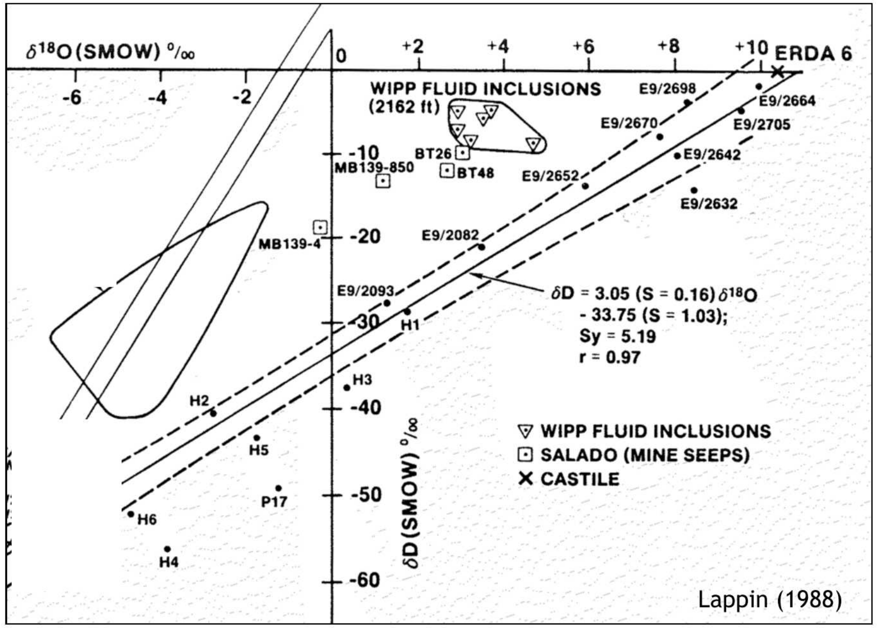


<u>Data will inform:</u>

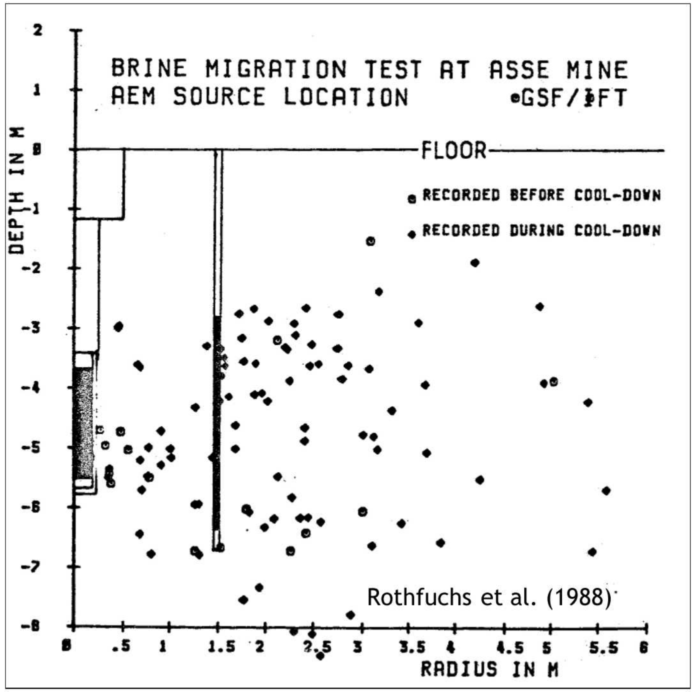
- Gases produced from heating salt
- Isotopic identification of 3 brine types
- Advection / diffusion /reaction (tracer)



Cavity ringdown Spectrometer (CRDS)



Acoustic Emissions (AE)



Rothfuchs et al. (1988)

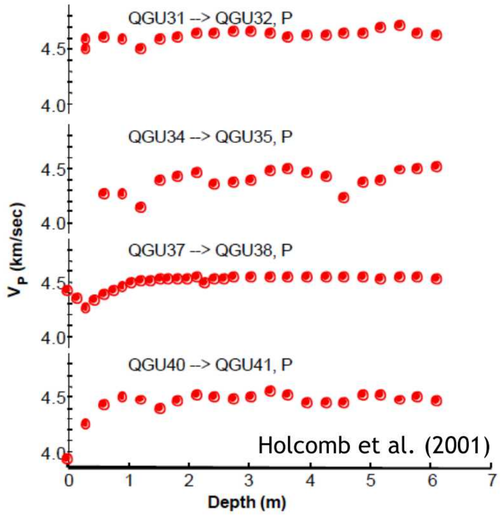
Listen to salt with piezoelectric transducers

Passive AE

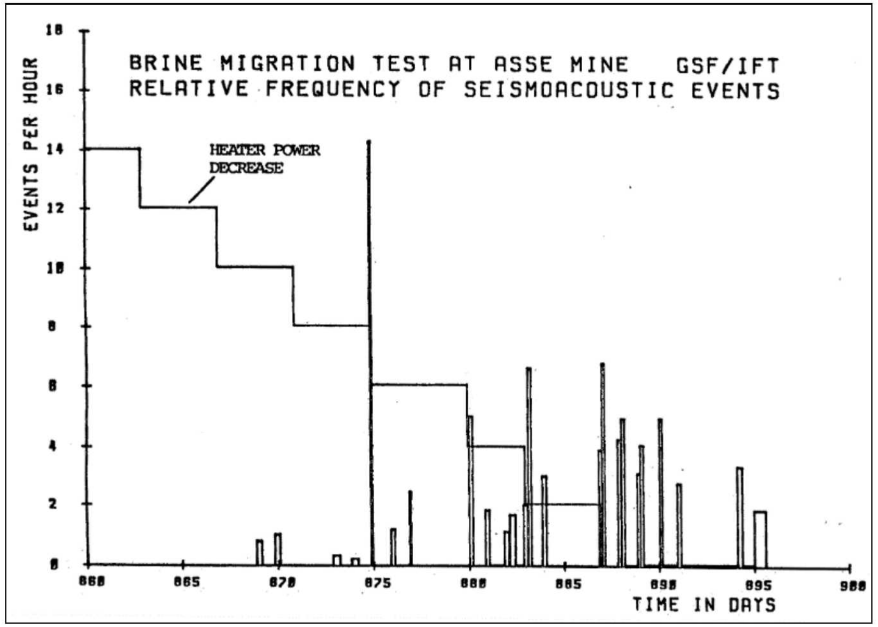
- Salt cracking during heat up & cool-down
- Triangulate AE sources around heated borehole
- AE correlated with permeability increases

Active AE

- "Ping" sensors while listening, estimate travel times
- Lower velocity in damaged rock



Holcomb et al. (2001)



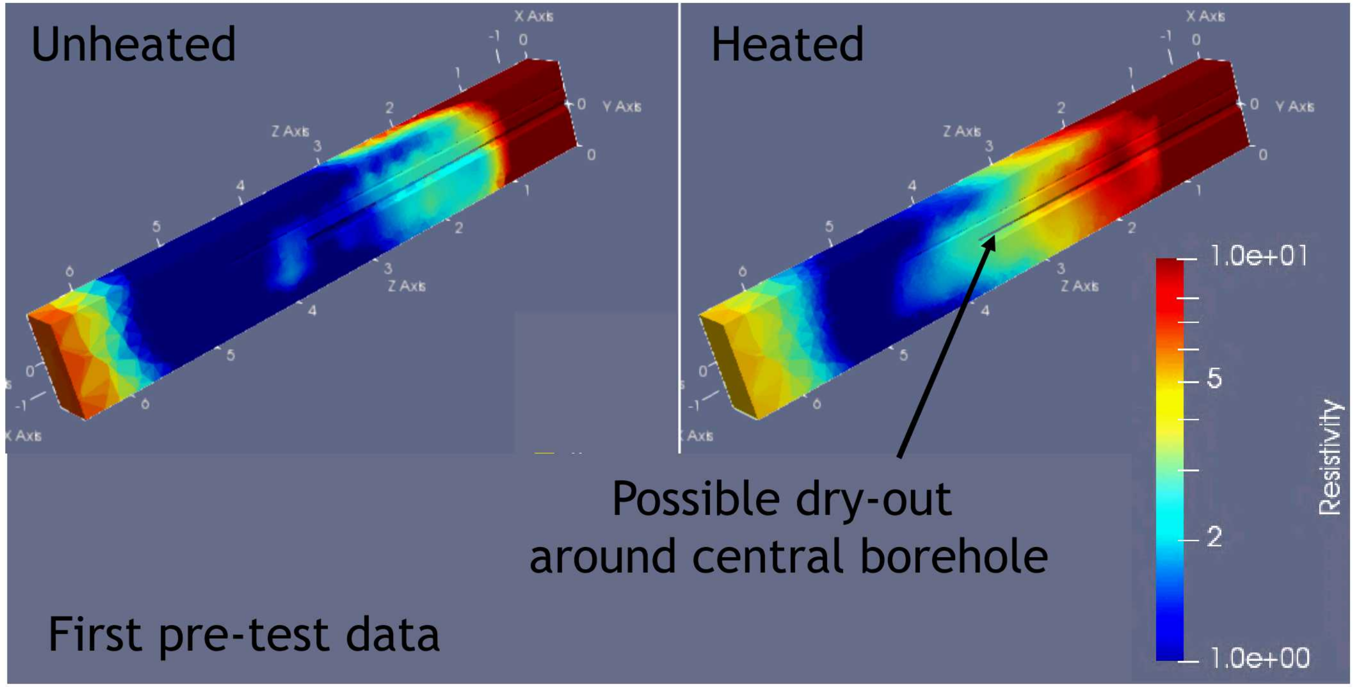
Data will inform:

- Where & when damage occurs

Electrical Resistivity Tomography (ERT) and Fiber Optics

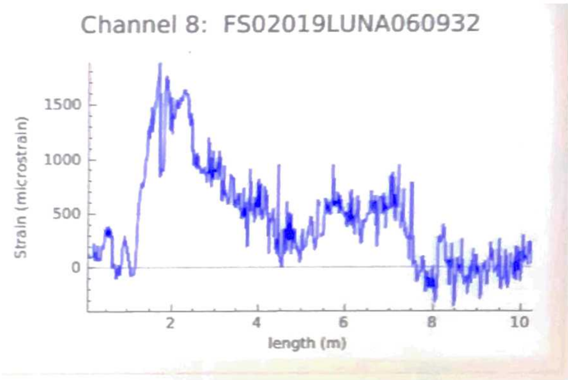
ERT: Measure voltage from applied current at every electrode pair

- Multiple AC frequencies (1-10 Hz)
- Electrodes grouted into boreholes
- Data will inform evolution of brine content (i.e., dry-out)



Fiber-optic distributed sensing

- Scattering in grouted fiber-optics
- Measure temperature and strain
  - Sub-mm resolution in space
  - 1 Hz resolution in time



Cementitious Seals

Emplace pre-fabricated cement plugs

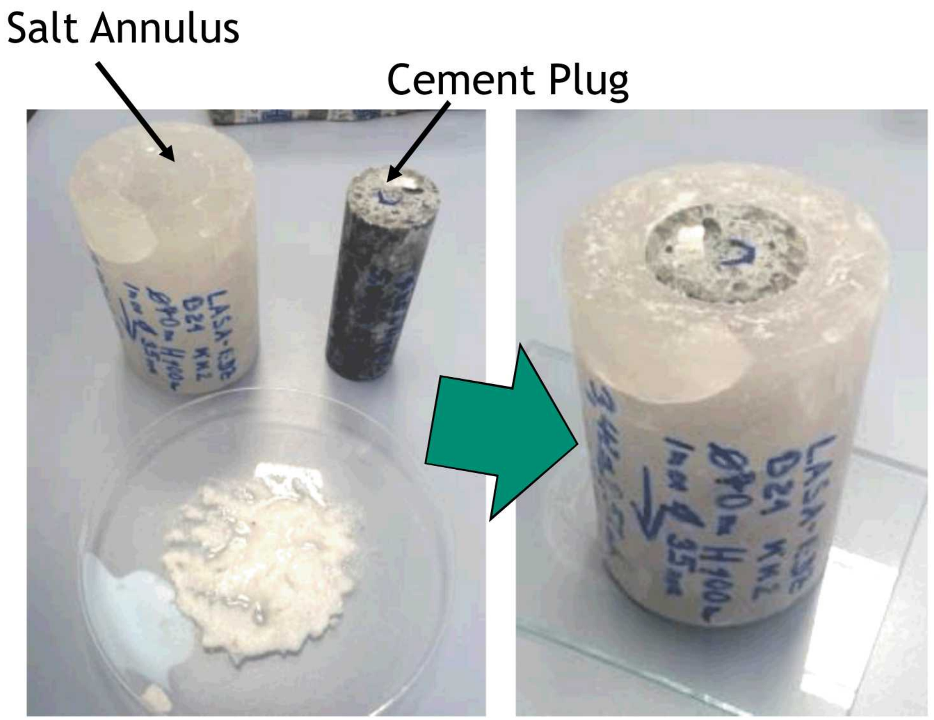
- Satellite borehole (SL)
- Monitor strain as borehole closes
- Upscale GRS lab seals tests

Overcore post-test to analyze interfaces

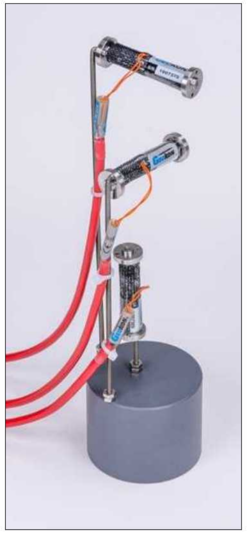
Compare:

- Sorel cement (MgO) and salt concrete plugs
- Heated and unheated conditions

Observe salt / brine / cement interactions



Czaikowski & Wieczorek (2016)



Test Status

Boreholes drilled (Feb-Apr 2019)

Installed instrumentation (May-Aug 2019)

Power turned on in drift Aug 2019

Plumbed and wired experiment (Sept-Oct 2019)

Follow-on tests at different temperatures (2020)