Site Characterization for the Deep Borehole Field Test

Kristopher L. Kuhlman

Sandia National Laboratories

September 26, 2016; SAND2016-9387C
What is the Deep Borehole Field Test?

What are we trying to observe?

How are we planning on measuring it?

How is this field test unique?
Deep Borehole

- **Disposal Concept**
  - Possible robust isolation from shallow geosphere
  - Barriers
    - Depth
    - Salinity & perm. gradients
  - Lack of driving forces
  - Diffusion dominated

- **Field Test**
  - 8.5” & 17” boreholes to 5 km
  - Technical demonstration
    - Drilling
    - Sampling & *in situ* testing
    - Surface/downhole handling
  - *No waste*
Deep Borehole Conceptual Profiles

**Sources of Salinity**
- Evaporite dissolution
- $H_2O$-rock interactions
- Ancient seawater
- Fluid inclusions

**Controls on Permeability**
- Increasing confining stress
- Fracture zones
- Mineral precipitation
- Overpressure $\rightarrow$ hydrofracture

**Geothermal Gradient**
- Radioactive decay
- Regional heat flux

Sedimentary Overburden $\leq 2$ km
- Crystalline Basement $\geq 3$ km
Observed Profiles

Salinity Increases with Depth

Bulk Permeability Decreases with Depth

DeMaio and Bates (2013)

Stober and Bucher (2007)
Observed Profiles

Salinity Increases with Depth

Bulk Permeability Decreases with Depth

DeMaio and Bates (2013)

Stober and Bucher (2007)

Clauser (1992)

Observed Profiles

Salinity Increases with Depth

- TDS (g/L)
- Depth (m)

DeMaio and Bates (2013)

Bulk Permeability Decreases with Depth

- Log K (m s⁻¹)
- Depth (km)

Stober and Bucher (2007)

Bulk Permeability Increases with Scale

Clauser (1992)

Upscaling permeability data

vs.

Geochemical composition and natural tracers data
Sampling Profiles

- Borehole Geophysics
- Logging During Drilling
  - Mud fluids/tracers/dissolved gases
- Basement Rock Samples
  - Coring (5%, 150 m total)
  - Drill Cuttings/Rock Flour (XRD + XRF)
- Formation Fluid Samples
  - Pumped from high-perm intervals
  - Extracted from cores
- Formation Fluid (& Mud) Analytes
  - Onsite fluid density/temperature
  - Major ions & trace metals
  - C, N, S, Sr & U isotope ratios
  - $^4$He buildup in fluids & qtz. crystals
  - Stable water isotopes
In Situ Testing

- **Flowing Borehole Logs**
  - Salinity dilution & temperature diffusion

- **Hydrologic Tests**
  - Low-perm pulse tests (5)
  - High-perm pumping tests (5)
  - Estimate:
    - Static formation pressure
    - Permeability / compressibility / skin

- **Injection-Withdrawal Tracer Tests (2)**

- **Hydromechanical Packer Test (1)**
  - Estimate $k_{DRZ}(\sigma)$

- **Hydraulic Fracturing Stress Tests (5)**
  - Estimate $\sigma_h$ & $\sigma_H$ magnitudes
  - Test unfractured & existing fracture intervals
Summary and Uniqueness

- **DBFT Likely Different From:**
  - Oil/gas or mineral exploration (low perm., low porosity rocks)
  - Geothermal exploration (low geothermal gradient)
  - Shallow drilling/testing (high $p$, high $\sigma$, deep, breakouts)

- **DBFT Characterization Approach**
  - Not exhaustive permeability characterization (scaling)
  - Seeking *geochemical* evidence of system isolation
  - Use “off-the-shelf” approaches when available

- **DBFT Goals**
  - Drill straight large-diameter boreholes to 5 km depth
  - Demonstrate sample collection (cores + formation fluid)
    - Enough samples
    - Low enough contamination level
  - Demonstrate *in situ* testing at depth (3 to 5 km)