Exceptional service in the national interest

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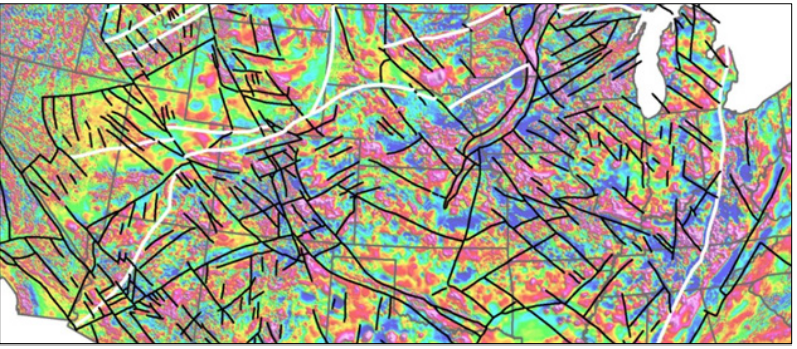

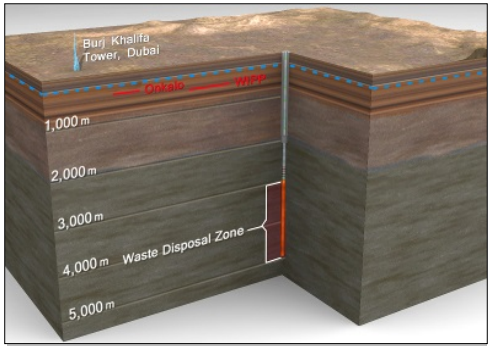

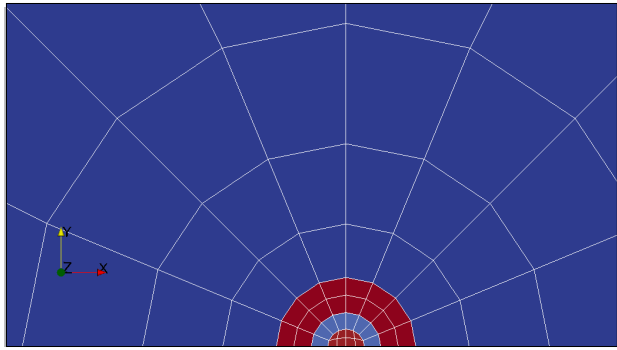

Site Characterization for the Deep Borehole Field Test

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Sandia National Laboratories

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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What is the Deep Borehole Field Test?

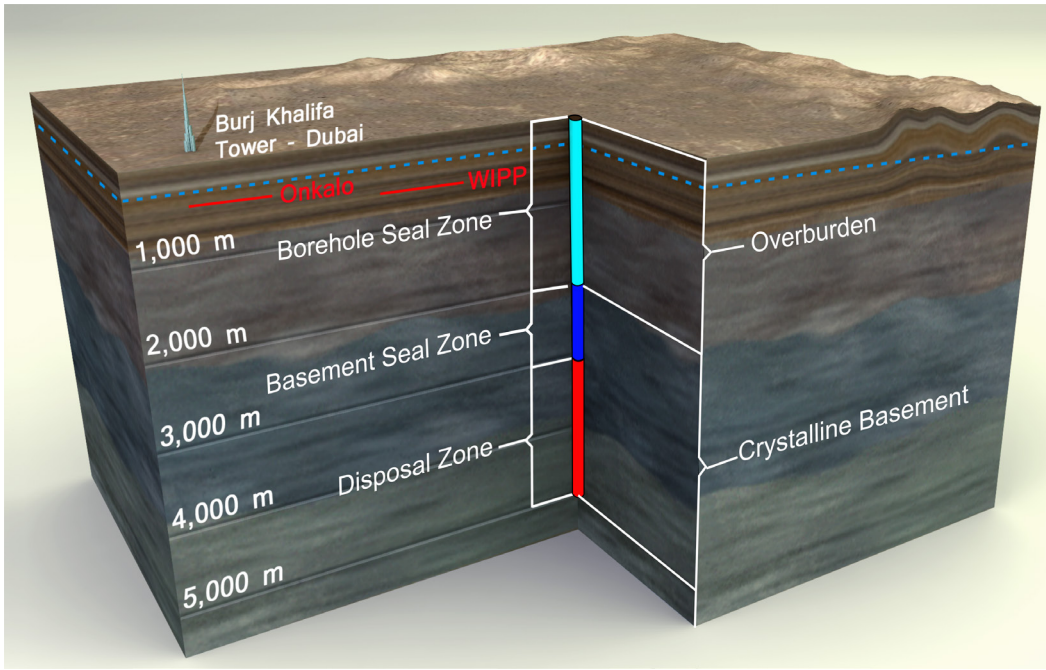
What are we trying to observe?

How are we planning on measuring it?

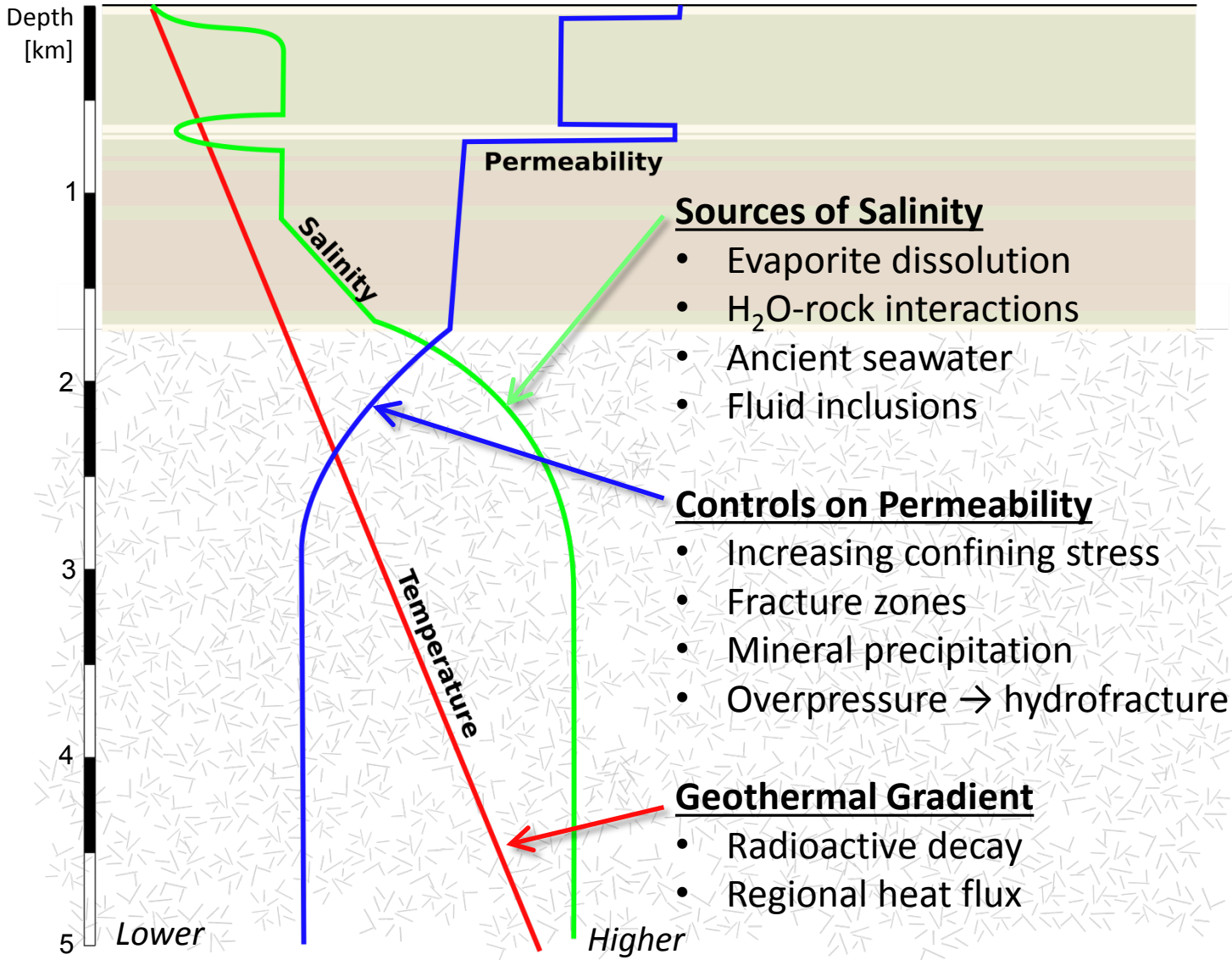
How is this field test unique?

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 → hydrofracture

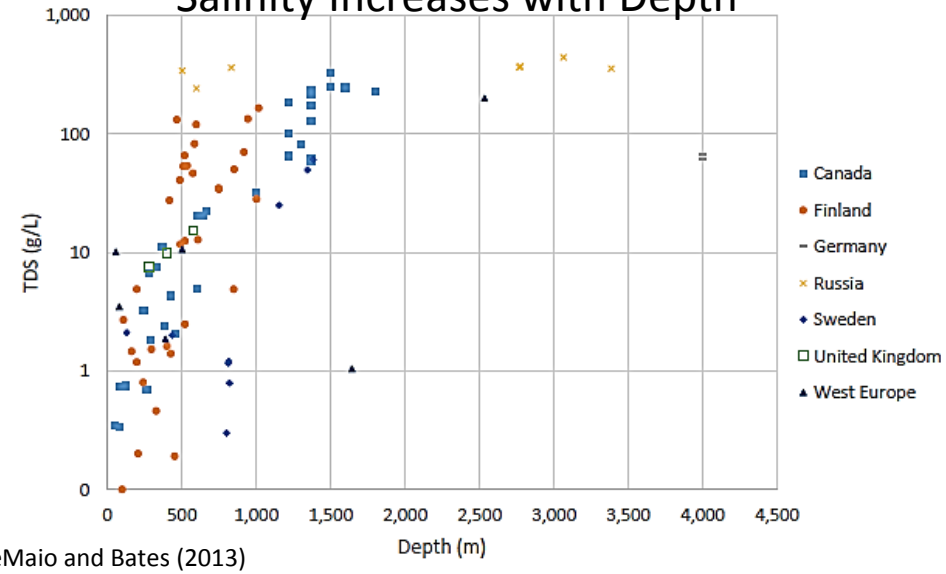
Geothermal Gradient
- Radioactive decay
- Regional heat flux

Sedimentary Overburden ≤ 2 km

Crystalline Basement ≥ 3 km

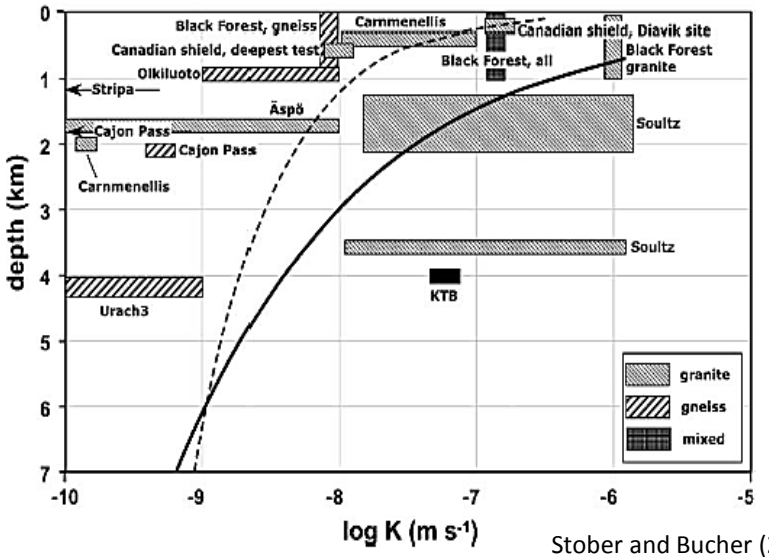
Observed Profiles

Salinity Increases with Depth



DeMaio and Bates (2013)

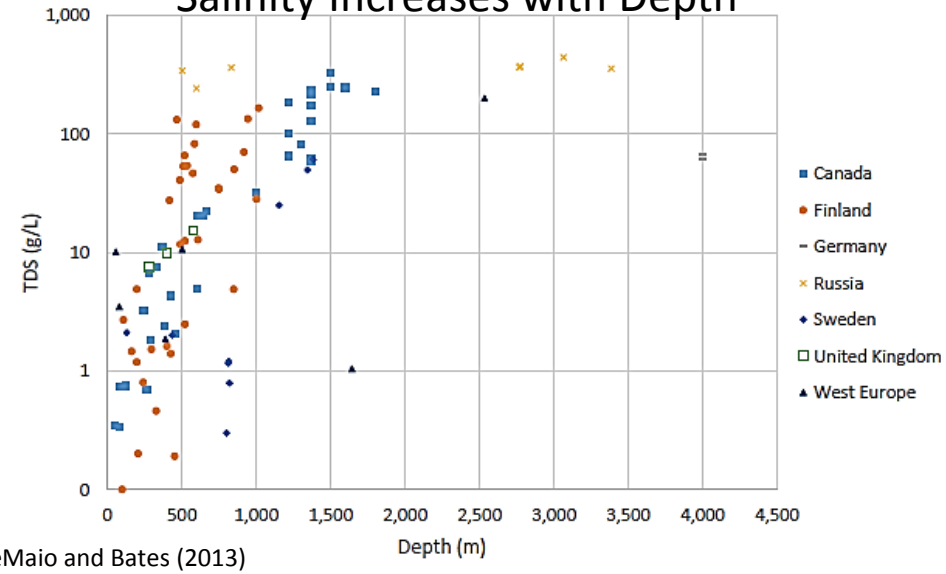
Bulk Permeability Decreases with Depth



Stober and Bucher (2007)

Observed Profiles

Salinity Increases with Depth



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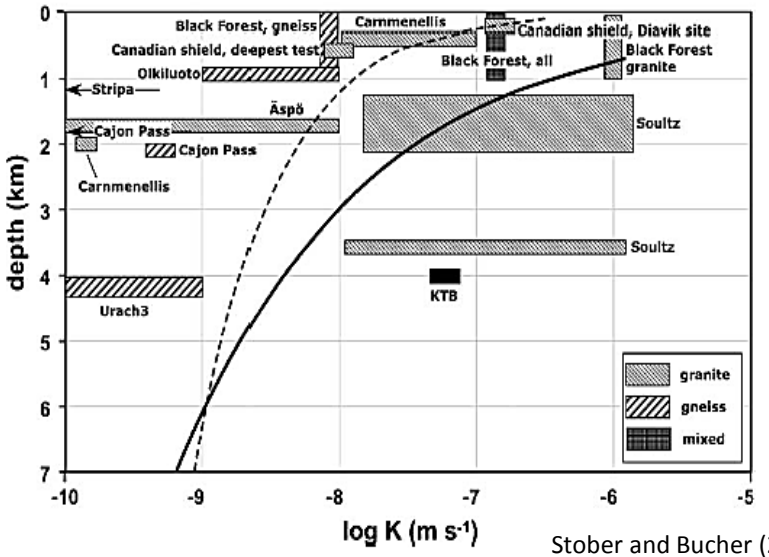

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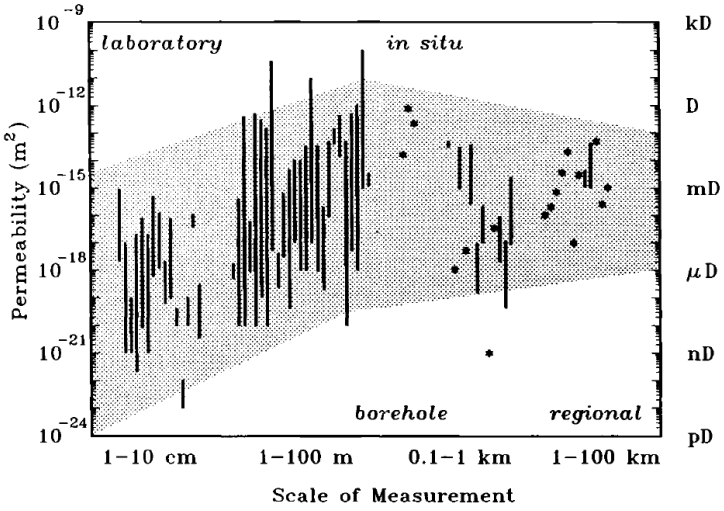
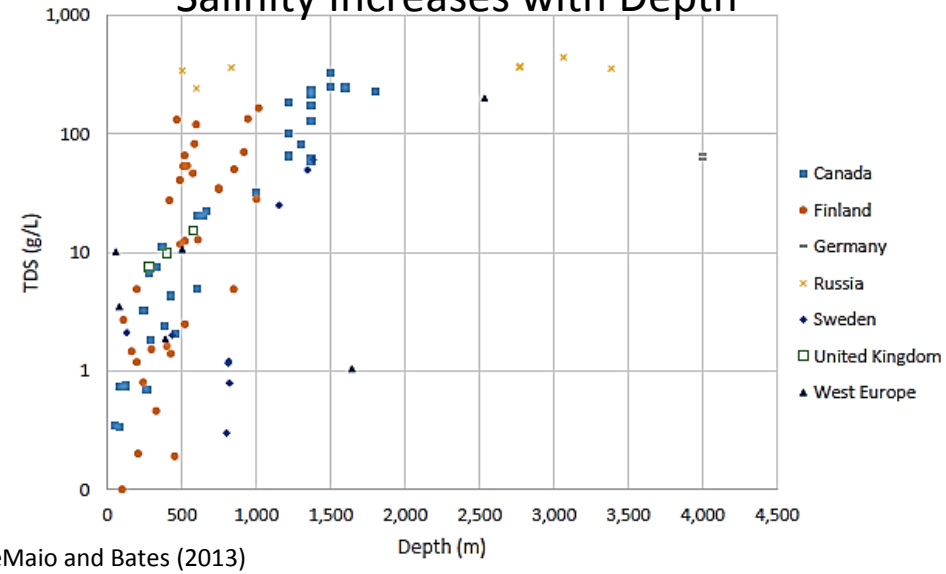


Bulk Permeability Increases with Scale

Clauser (1992)

Observed Profiles

Salinity Increases with Depth



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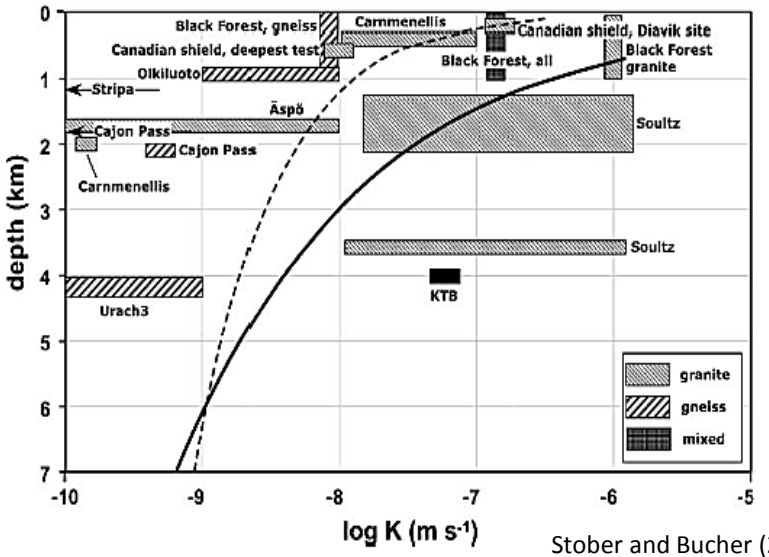

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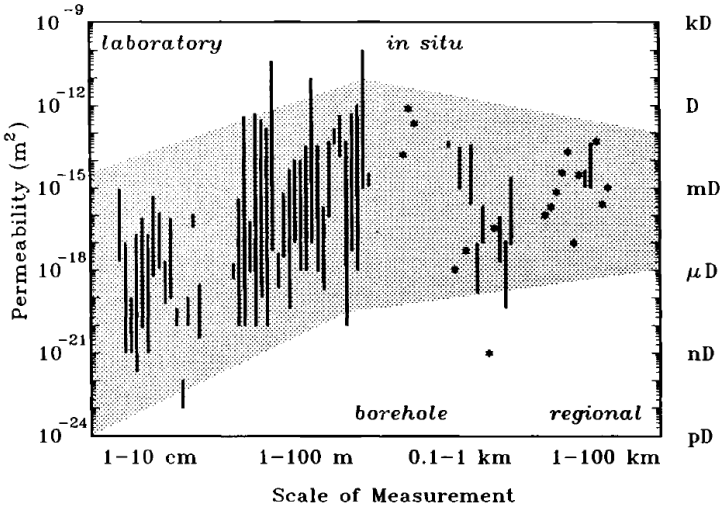


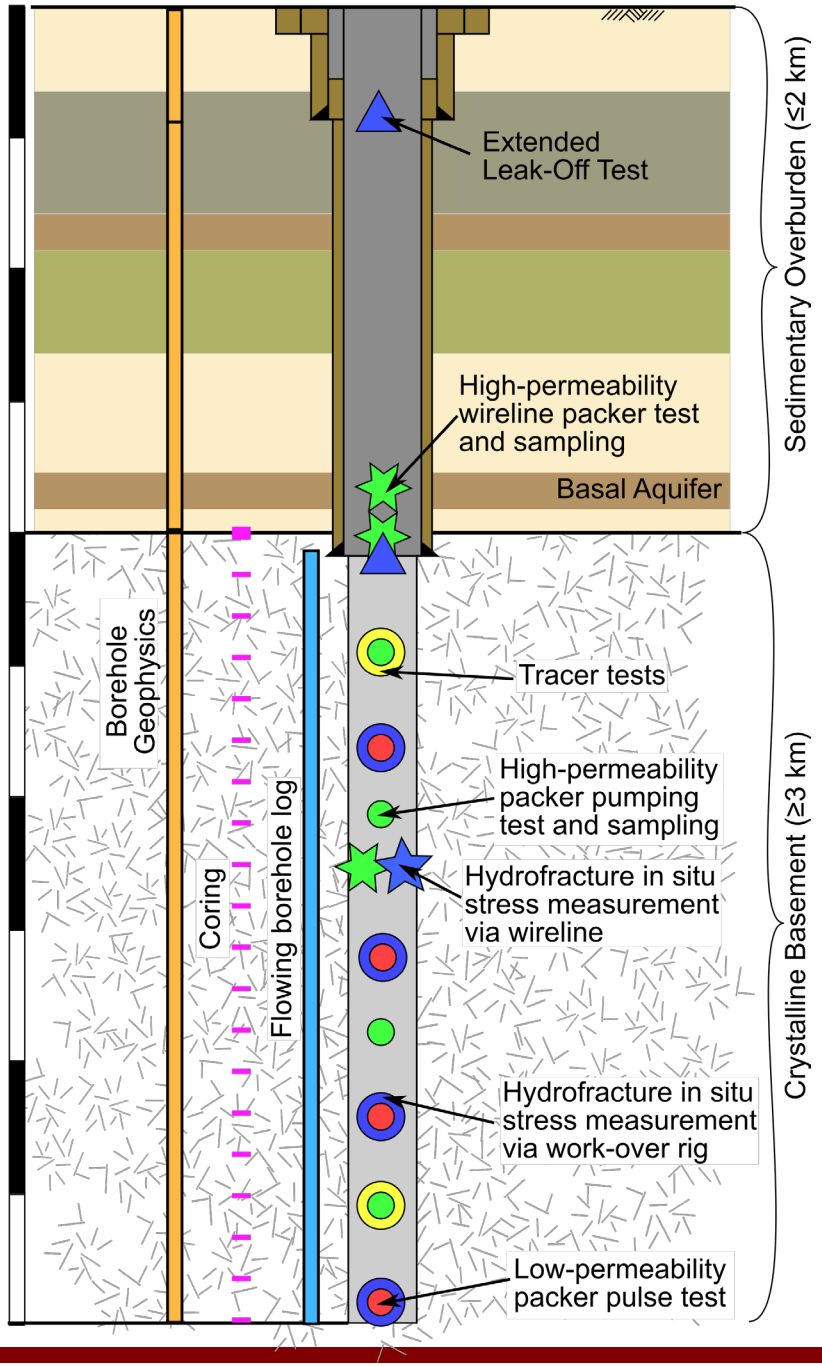
Bulk Permeability Increases with Scale

Clauser (1992)

Upscaling permeability data vs. Geochemical composition and natural tracers data

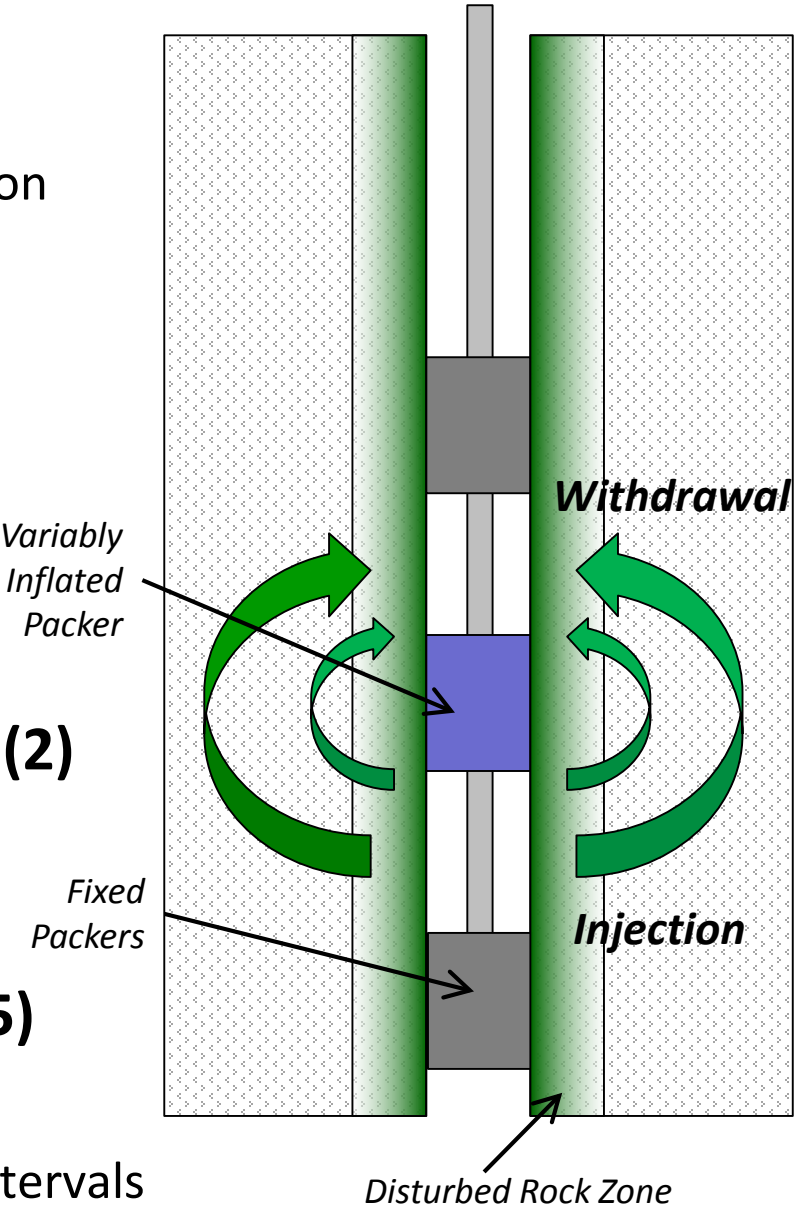
Sampling Profiles

- **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 σ_h & σ_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 σ, 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)