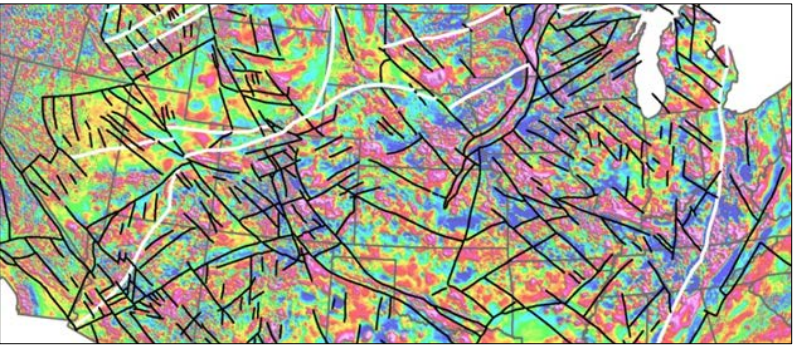
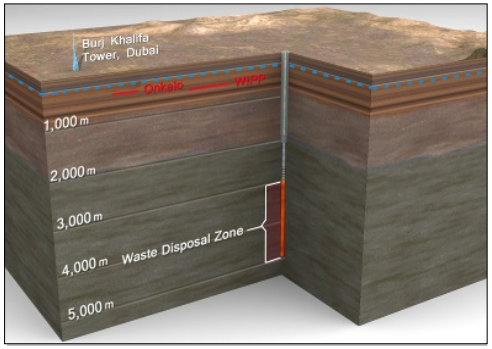
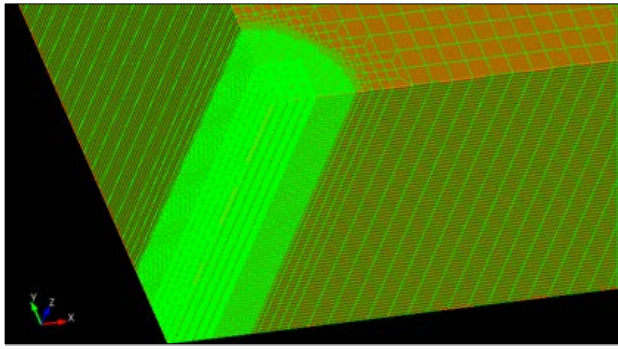
Exceptional service in the national interest

Sandia National Laboratories







Deep Borehole Field Test Site Characterization

Kristopher L. Kuhlman, Bill W. Arnold, Patrick V. Brady,
David C. Sassani, Geoff A. Freeze, Ernest L. Hardin

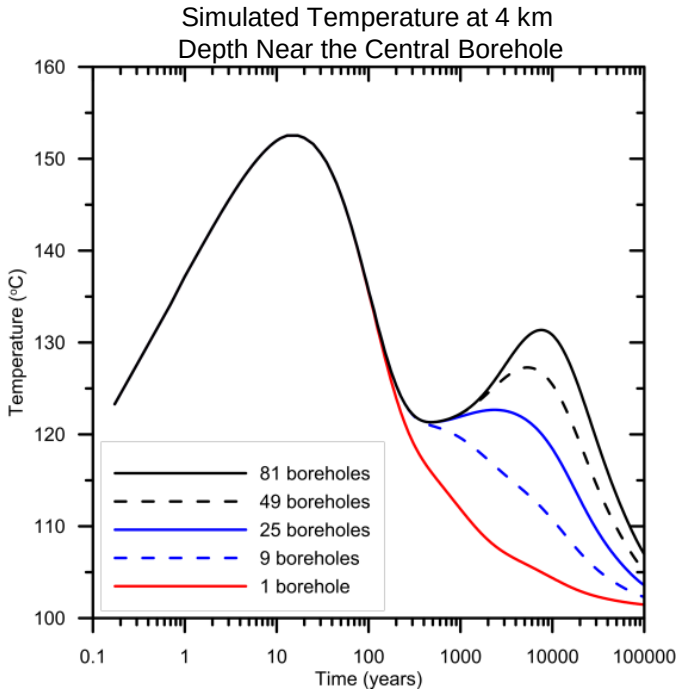
Sandia National Laboratories

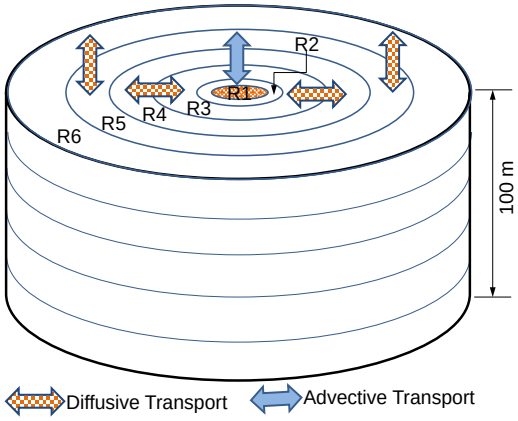
U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND2015-2665C

Deep Borehole Disposal Concept

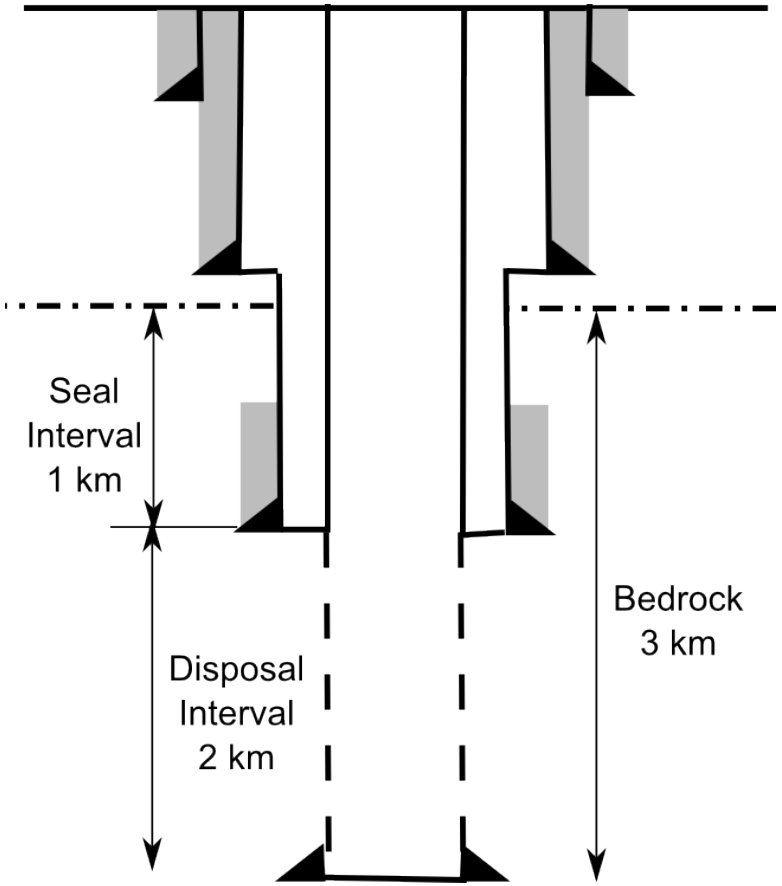




- **Straightforward construction**
- **Significant geologic isolation**
- **Modeling: no radioactive release over 1M years**

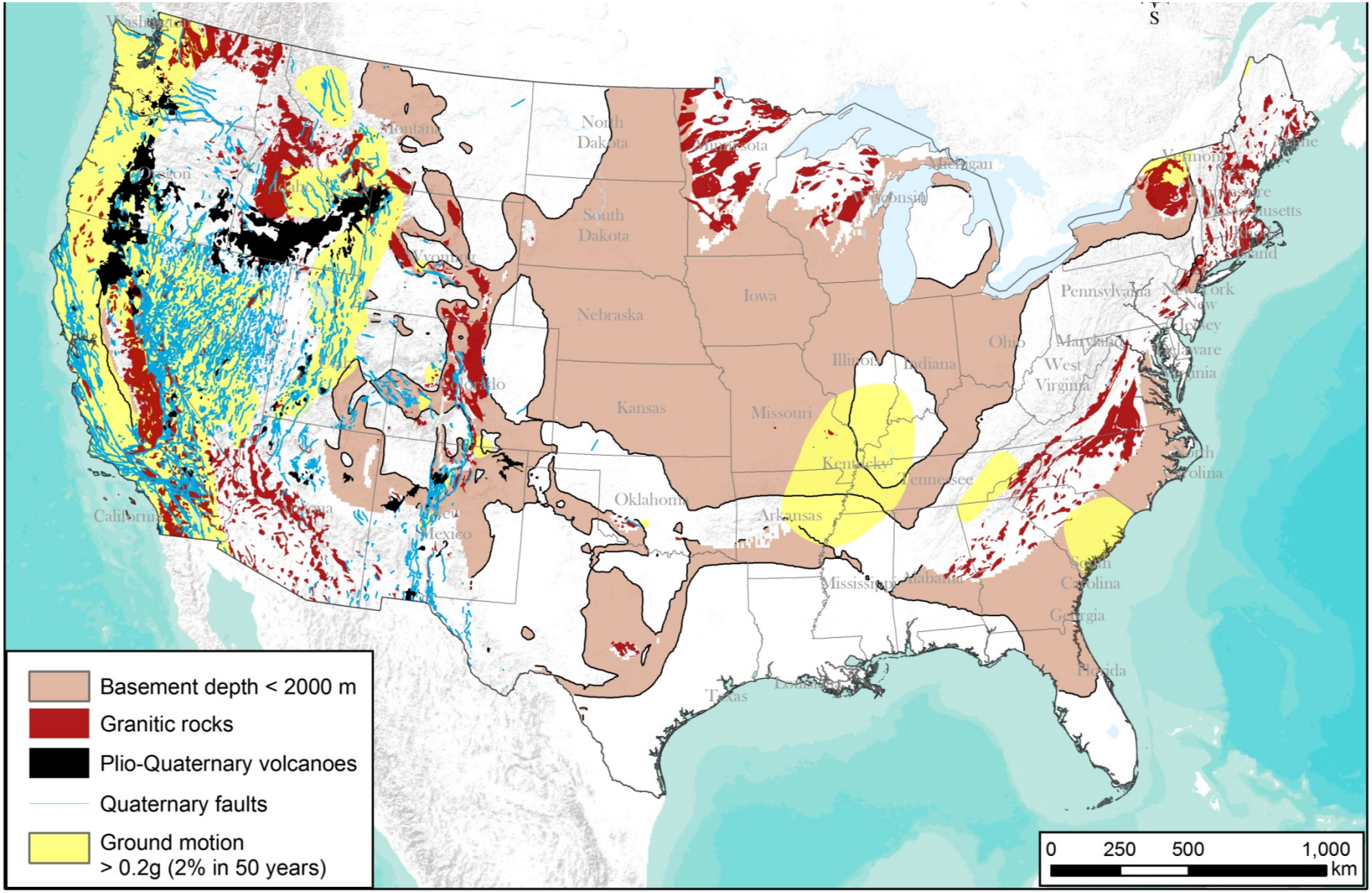
Deep Borehole Disposal Concept

- **Deep borehole radioactive waste disposal**
  - Boreholes in crystalline rock to 5 km TD
  - 3 km bedrock / 2 km overburden
  - Top 1 km of bedrock for seal
  - Lower 2 km disposal
  - Tectonically inactive crystalline bedrock
- **Deep borehole field test**
  - Department of Energy – Office of Nuclear Energy (DOE-NE)
  - FY 2015-2019 project
  - Drill two boreholes to 5 km
  - Demonstration of science and engineering supporting idea



Geology: Siting and Characterization

Sandia National Laboratories



Deep Borehole Field Test

Sandia National Laboratories

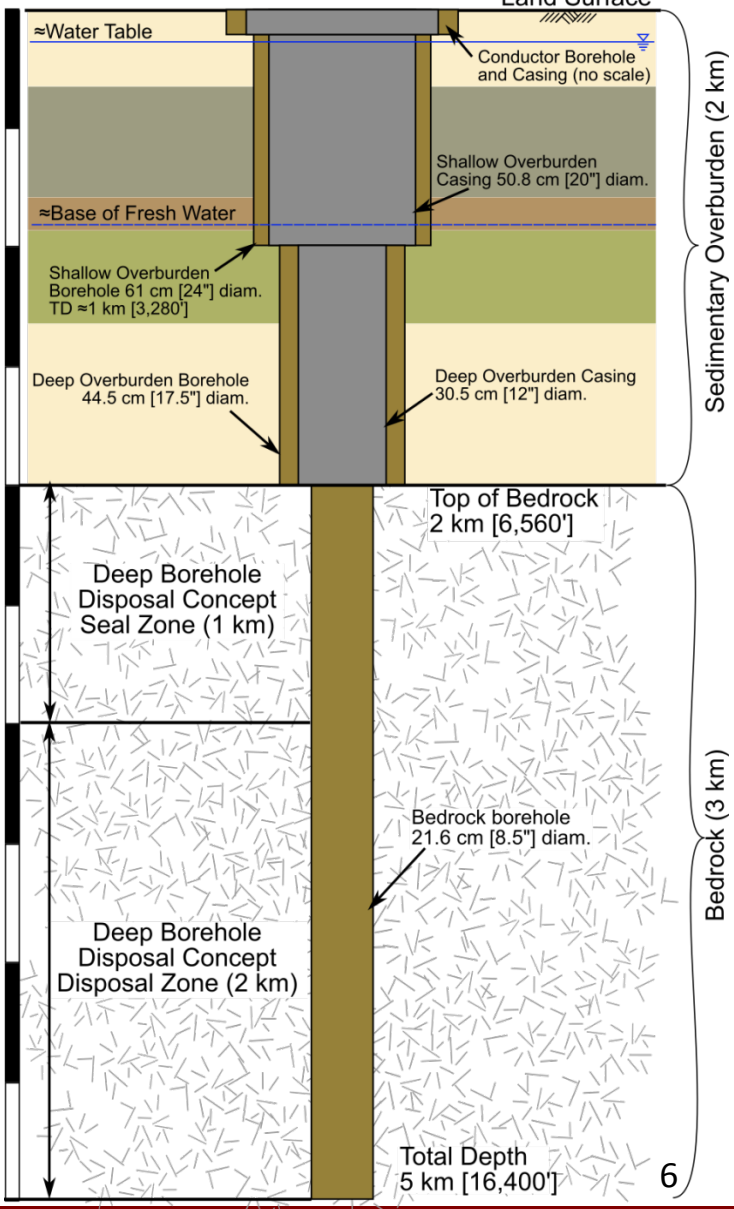
- **Drill two 5-km boreholes**
  - **Characterization Borehole (CB): 21.6 cm [8.5”] diam. @ TD**
  - **Field Test Borehole (FTB): 43.2 cm [17.5”] diam. @ TD**

- **Prove ability to:**
  - **Drill deep, wide, straight borehole safely (CB + FTB)**
  - **Characterize bedrock (CB)**
  - **Test formations in situ (CB)**
  - **Collect geochemical profiles (CB)**
  - **Emplace/retrieve surrogate canisters (FTB only)**

Characterization Borehole

- Drill/case sedimentary section
  - Minimal testing (not DBFT focus)
- Drill bedrock section
  - Core 150 m of 3 km (5%)
  - Hydrofracture stress test
  - Borehole geophysics
  - Bedrock production log
  - Pore/fracture water samples
- Packer tool via work-over rig
  - Shut-in pressure tests
  - Packer pumping/slug tests
  - Tracer and heater tests

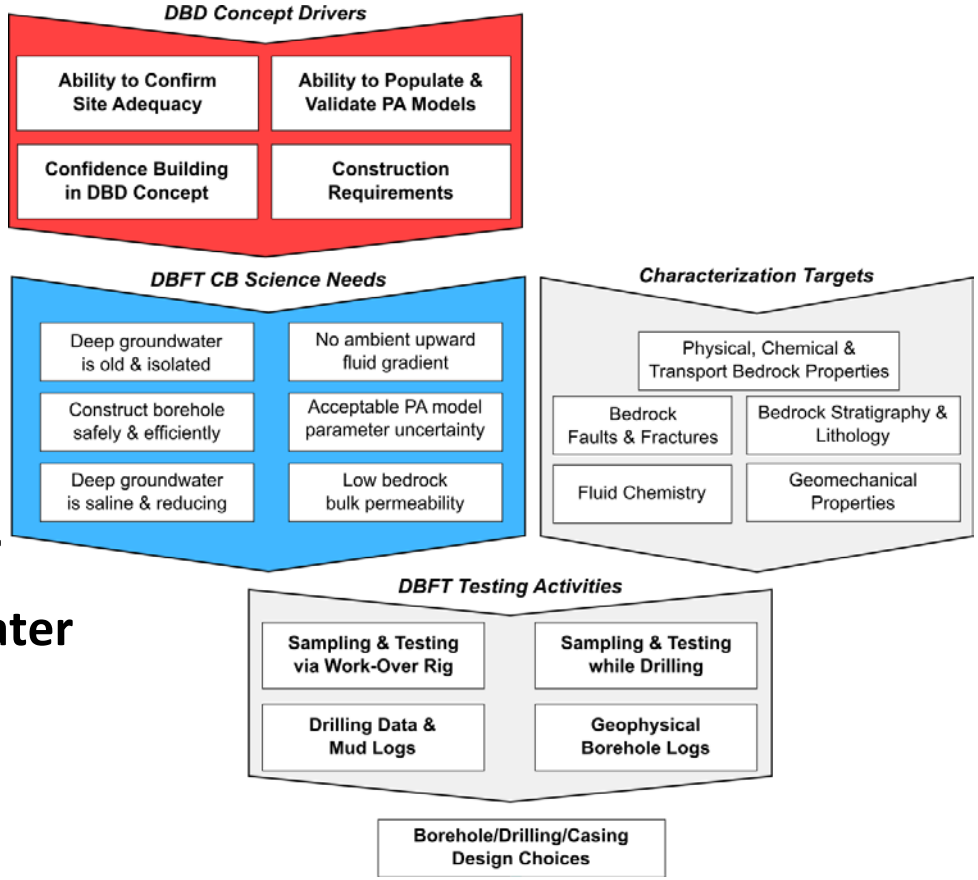
Borehole designed to maximize likelihood of good samples



Characterization Science Needs

- ***Drivers*** **for Science Needs in CB**
  - **Confirm site adequacy**
  - **Data for numerical models**
  - **Confidence building**
  - **Construction requirements**

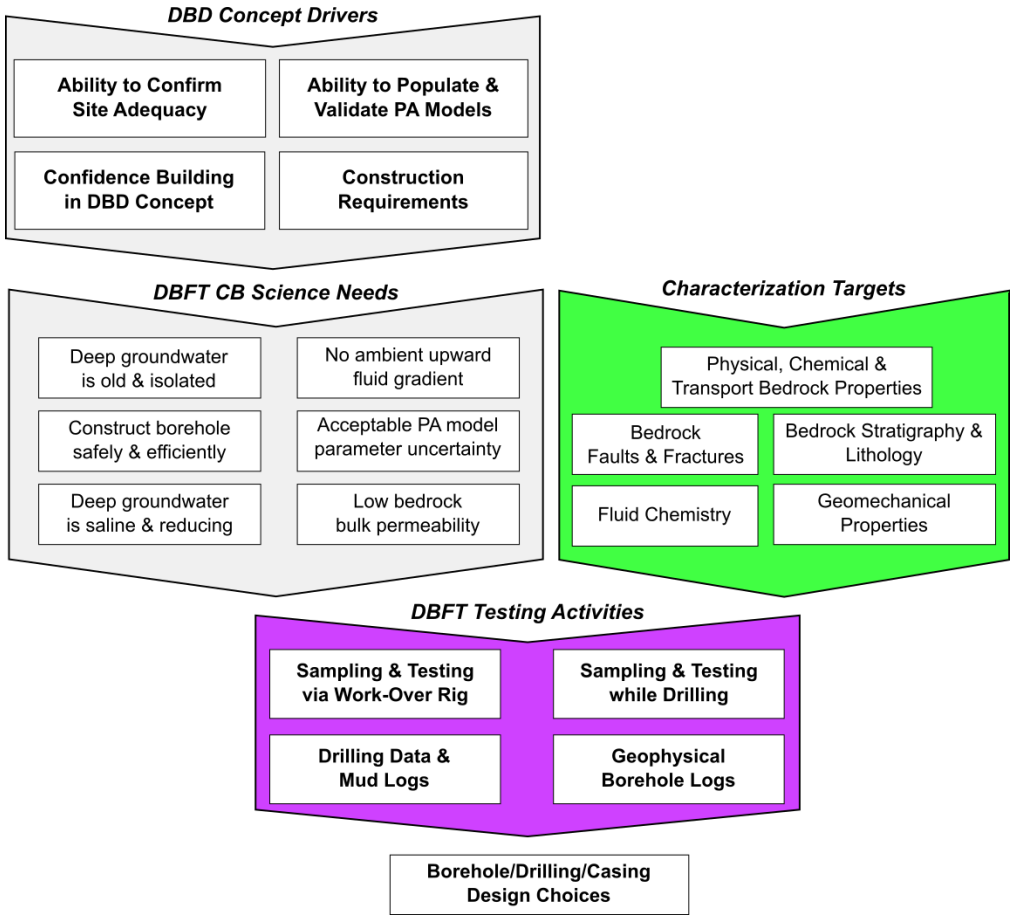
- ***Science Needs*** **in CB**
  - **Old & isolated deep groundwater**
  - **Saline & reducing deep groundwater**
  - **No ambient upward gradient**
  - **Low bedrock permeability**
  - **Acceptable model uncertainty**
  - **Safe & efficient borehole construction**



Characterization Targets/Methods

- ***Things to measure*** **in CB**
  - **Faults & fractures**
  - **Stratigraphy & lithology**
  - **Physical, chemical & transport properties**
  - **Fluid chemistry**
  - **Geomechanical properties**

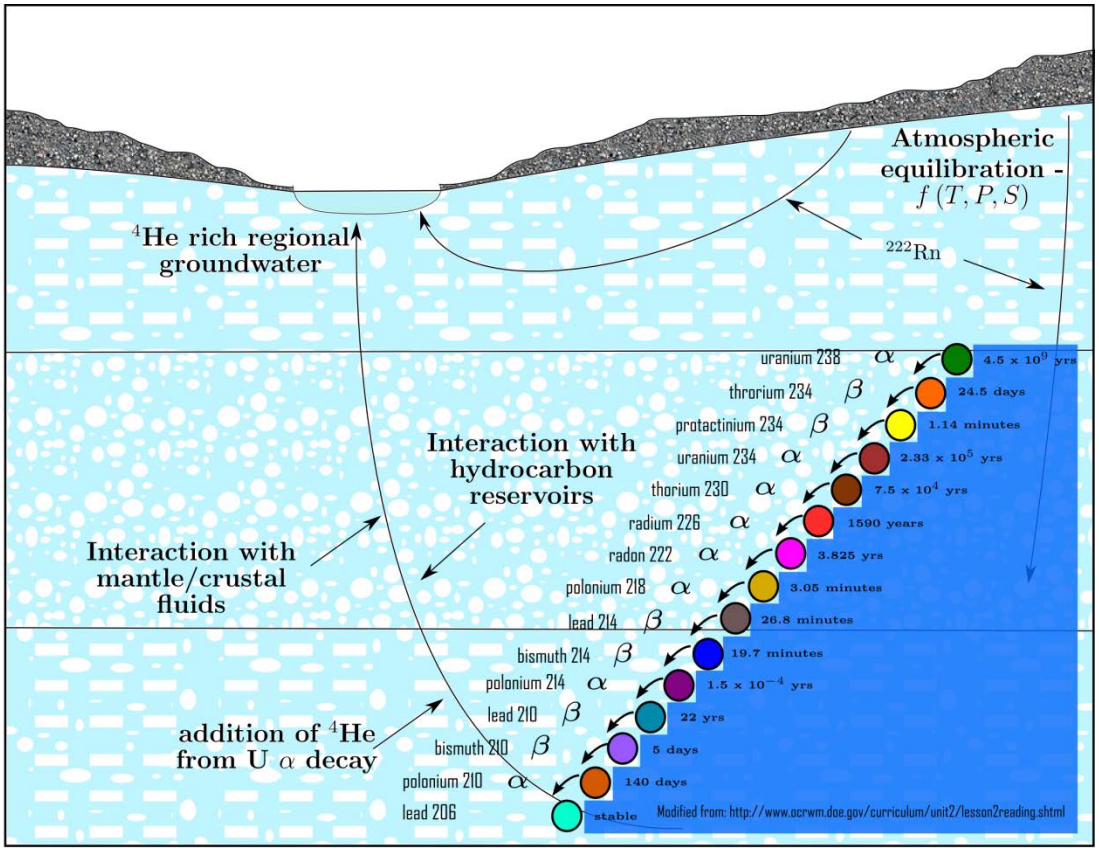
- ***Ways to measure*** **in CB**
  - **Drilling data and mud logs**
  - **Geophysical borehole logs**
  - **Sampling & testing**
    - **while drilling**
    - **work-over rig**



Environmental Tracer Profiles

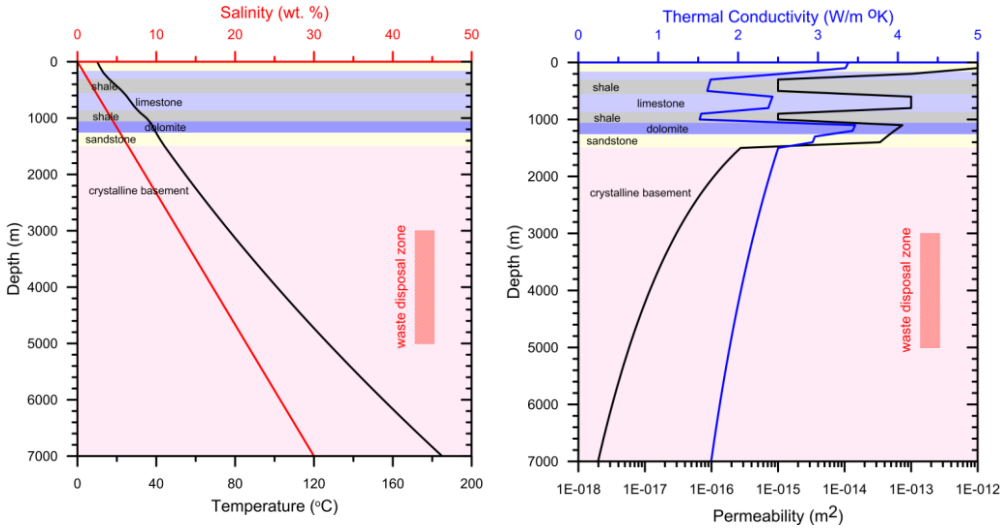
- **Important to Safety Case**
- **Vertical profiles**
  - **Noble gases**
  - **Stable water isotopes**
  - **Atmospheric radioisotope tracers (e.g., Xe)**
  - ***Sample quality/quantity!***
- **Long-term data**
  - **Flowpaths**

  Minerals → pores → fractures
  - **Confirms system stability**
    - **Density gradient**
    - **Temperature gradient**

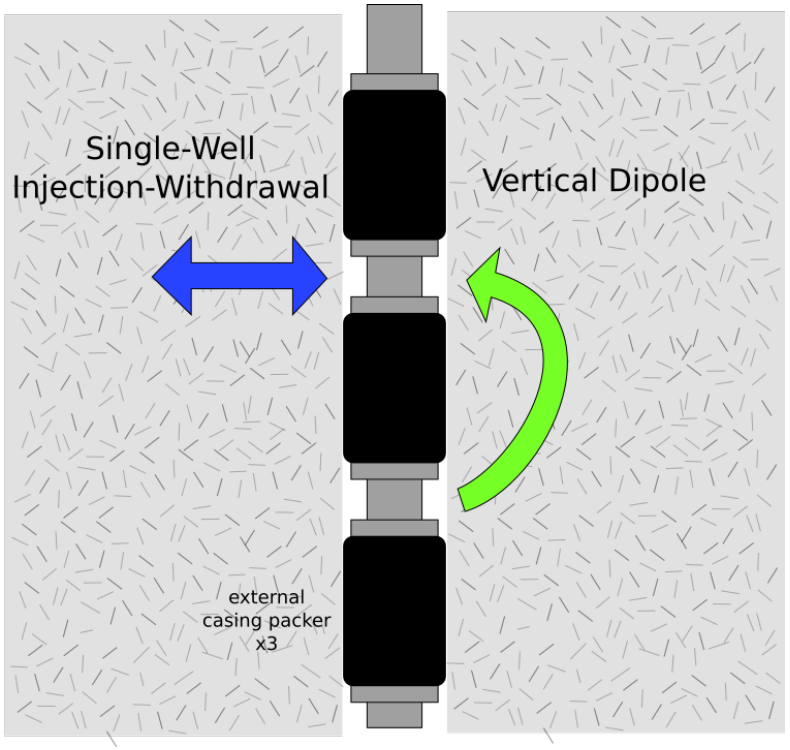


Hydrogeologic Testing

- **Hydrologic property profiles**
  - **Static formation pressure**
  - **Permeability / compressibility**



- **Borehole tracer tests**
  - **Single-well injection-withdrawal**
  - **Vertical dipole**
  - **Understand transport pathways**



Deep Borehole Field Test

Sandia National Laboratories

- **DB characterization/siting compared to:**
  - **Mined waste repositories**
    - **More geologic isolation – less "site mapping"**
    - **Single-phase fluid flow**
    - **Less steep pressure gradients**
  - **Oil/gas or mineral exploration**
    - **Crystalline basement vs sedimentary rocks**
    - **Low-permeability**
    - **Minimal mineralization**
    - **Avoid overpressure**
  - **Geothermal exploration**
    - **Low geothermal gradient**

Deep Borehole Field Test

Sandia National Laboratories

- **Demonstrate ability to**
  - **Safely construct 5-km large-diameter deep boreholes in bedrock**
  - **Construct safety case (numerical dry run with site data)**
  - **Construct environmental tracer profile**
  - **Safely emplace surrogate waste canisters (FTB only)**

- **Characterization goals**
  - **Confirm site adequacy**
  - **Populate and validate numerical models**
  - **Confidence building**
  - **Construction requirements**