*Exceptional service in the national interest*

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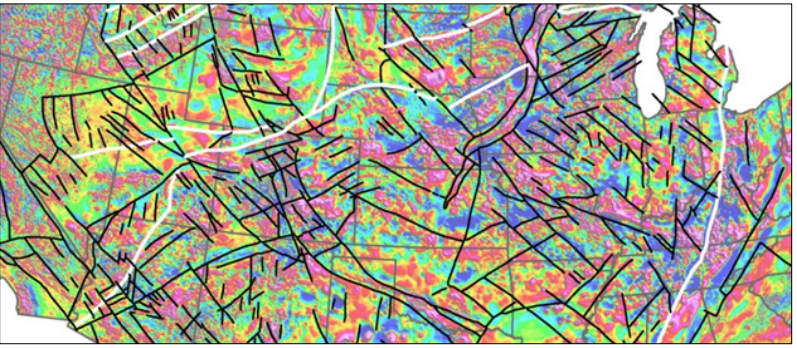

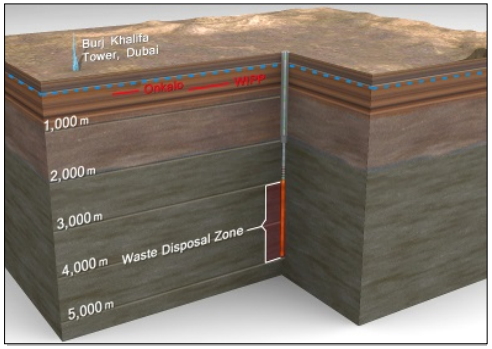


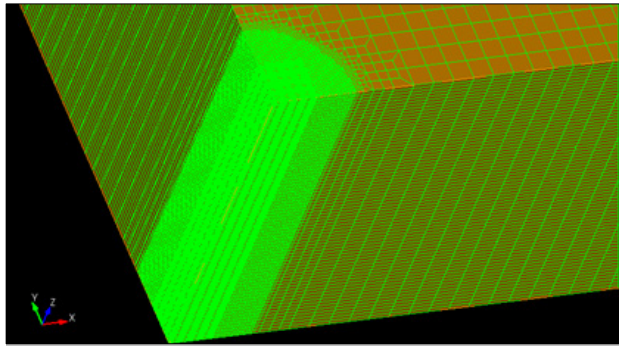

# Site Characterization for a Deep Borehole Field Test

**H13M-01**

**Kris Kuhlman,**

**Ernest Hardin, Geoff Freeze, David Sassani & Pat Brady**

*Sandia National Laboratories*

U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

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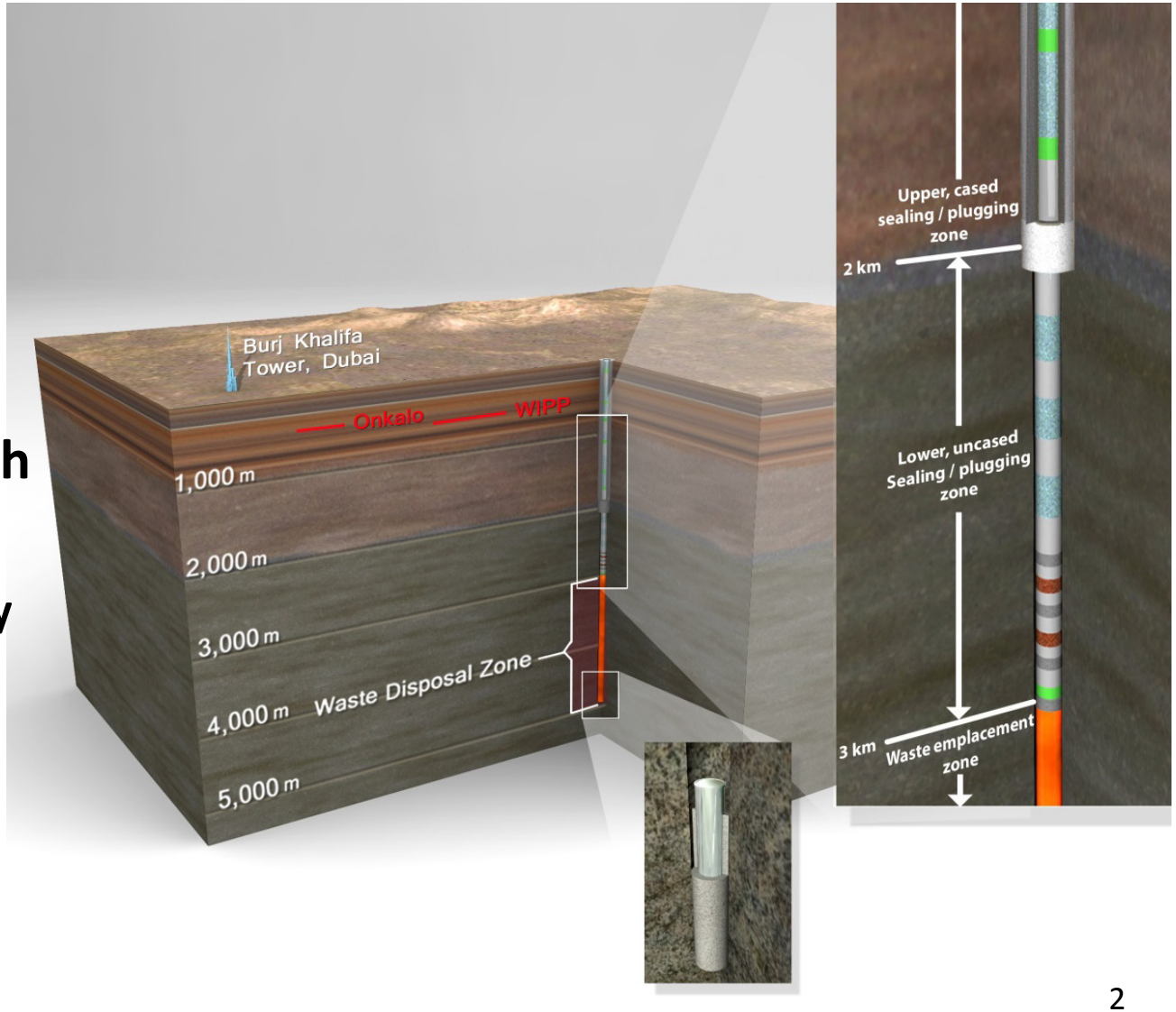
# Deep Borehole Disposal Concept

- ≤17” hole to 5 km
- Straightforward Construction
- Robust Isolation
- Conditions at Depth
  - Low permeability
  - Stable fluid density
  - Reducing fluid chemistry



# Deep Continental Drilling

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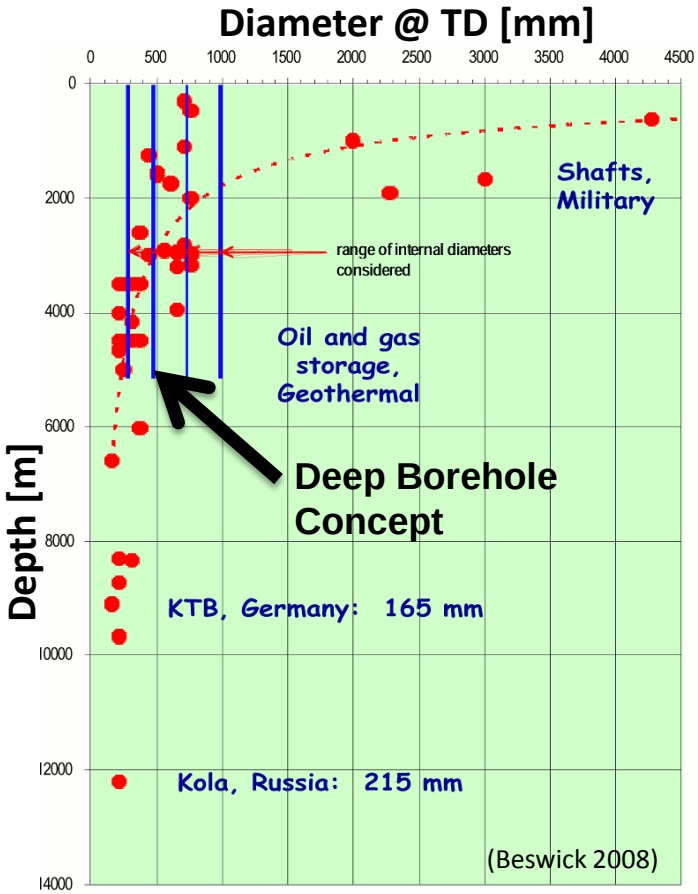
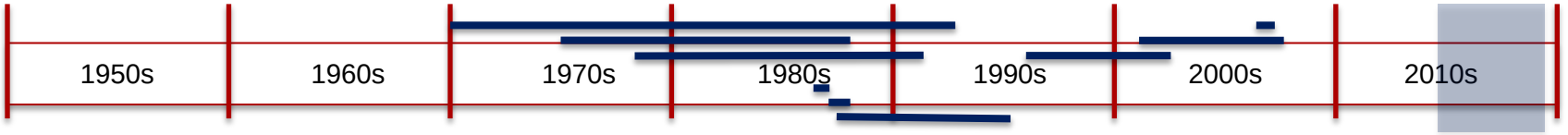
| Site | Location | Years | Depth [km] | Diam * [in] | Purpose |
|---|---|---|---|---|---|
| Kola SG-3 | NW USSR | 1970-1992 | 12.2 | 8½ | Geologic Exploration + Tech. Development |
| Fenton Hill | New Mexico | 1975-1987 | 4.6 | 9⅞ | Enhanced Geothermal |
| Urach-3 | SW Germany | 1978-1992 | 4.4 | 5½ | Enhanced Geothermal |
| Gravberg | Sweden | 1986-1987 | 6.6 | 6½ | Gas Wildcat |
| Cajon Pass | S California | 1987-1988 | 3.5 | 6¼ | Geologic Exploration |
| KTB | SE Germany | 1987-1994 | 9.1 | 6½ | Geologic Exploration + Tech. Development |
| Soultz-sous-Forêts GPK | NE France | 1995-2003 | 5.3 | 9⅝ | Enhanced Geothermal |
| SAFOD | Central California | 2002-2007 | 4 (3)# | 8¾ | Geology Exploration |
| Basel-1 | Switzerland | 2006 | 5 | 8½ | Enhanced Geothermal |

* borehole diameter at total depth

# true vertical depth




Deep Borehole Field Test
DBFT



# Wide Distribution of Potential Sites

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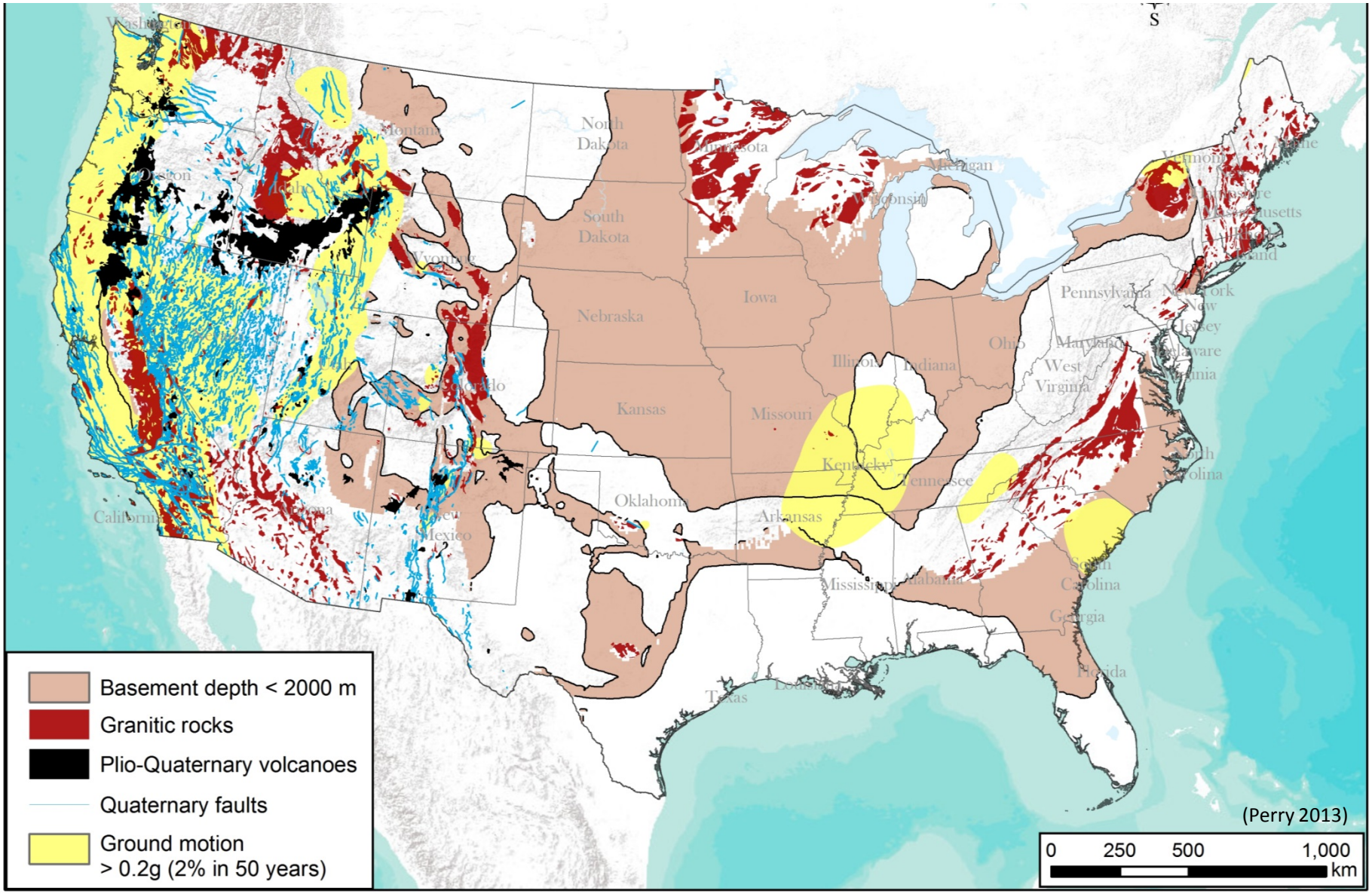
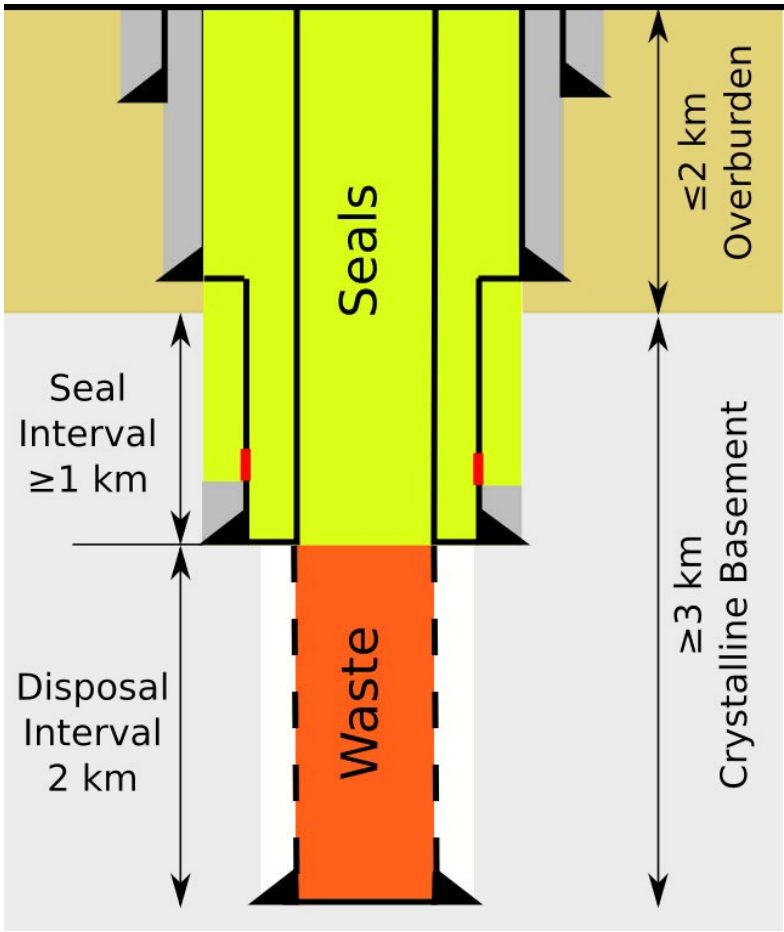


# Deep Borehole Concept & Field Test

Sandia National Laboratories

- **Deep Borehole Disposal (DBD)**
  - Boreholes to 5 km total depth (TD)
  - ≥3 km basement / ≤2 km overburden
  - ≥1 km basement seal
  - 2 km disposal zone
  - Single borehole or grid




- **Deep Borehole Field Test (DBFT)**
  - US Department of Energy - Office of Nuclear Energy (DOE-NE)
  - 2015-2019 Project
  - Two boreholes to 5 km TD
  - Science and engineering demonstration

# Deep Borehole Field Test (DBFT)

Sandia National Laboratories

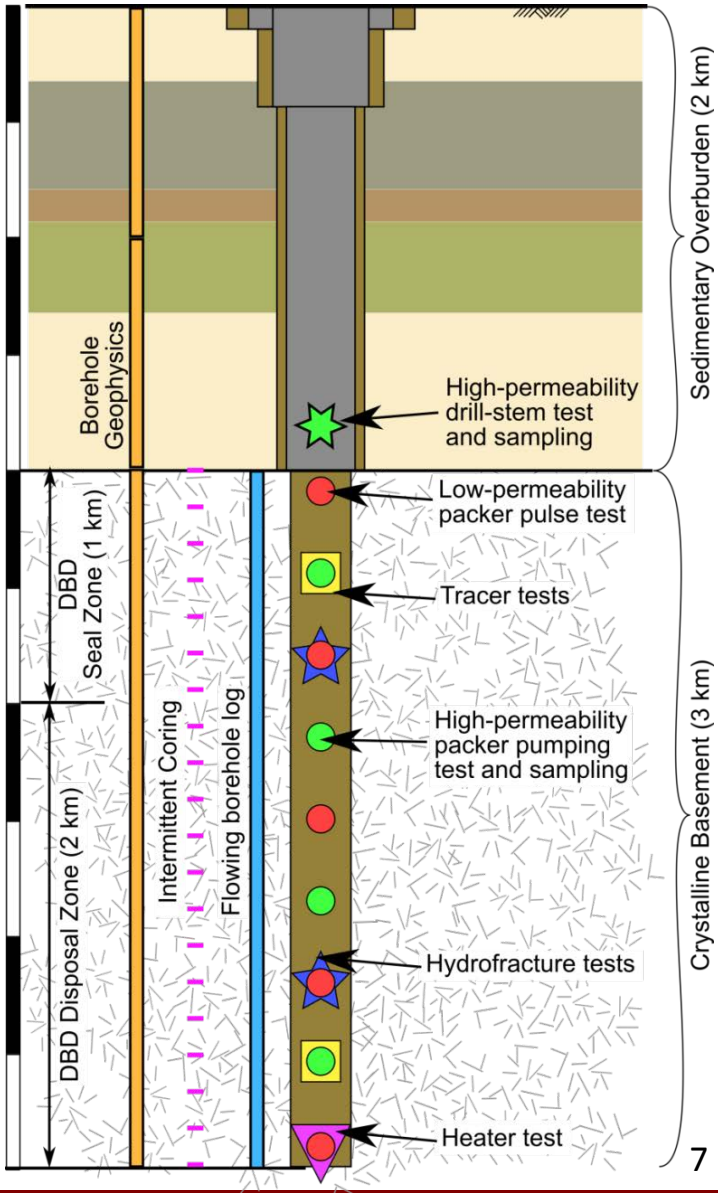
- **Construct Two 5-km Boreholes**
  - **Characterization Borehole (CB): 21.6 cm [8.5”] @ TD**
  - **Field Test Borehole (FTB): 43.2 cm [17”] @ TD**

- **Test Ability To:**
  - **Drill deep, wide & straight in crystalline rocks (CB + FTB)**
  - **Characterize bedrock via geophysics (CB)**
  - **In situ tests in basement ≤150°C & 50 MPa (CB)**
  - **Geochemical profiles (CB)**
  - **Emplace/retrieve test waste packages (FTB)**

# Characterization Borehole (CB)

- Not all Char. Methods Included
  - Surface geophysics
  - Testing sedimentary sequence
  - No need to demonstrate in DBFT
- 8.5” diam. ~geothermal experience
- Core 150 m of Bedrock Section
- Testing/Sampling After Completion
  - Packer tool via work-over rig
  - At limits of current technology

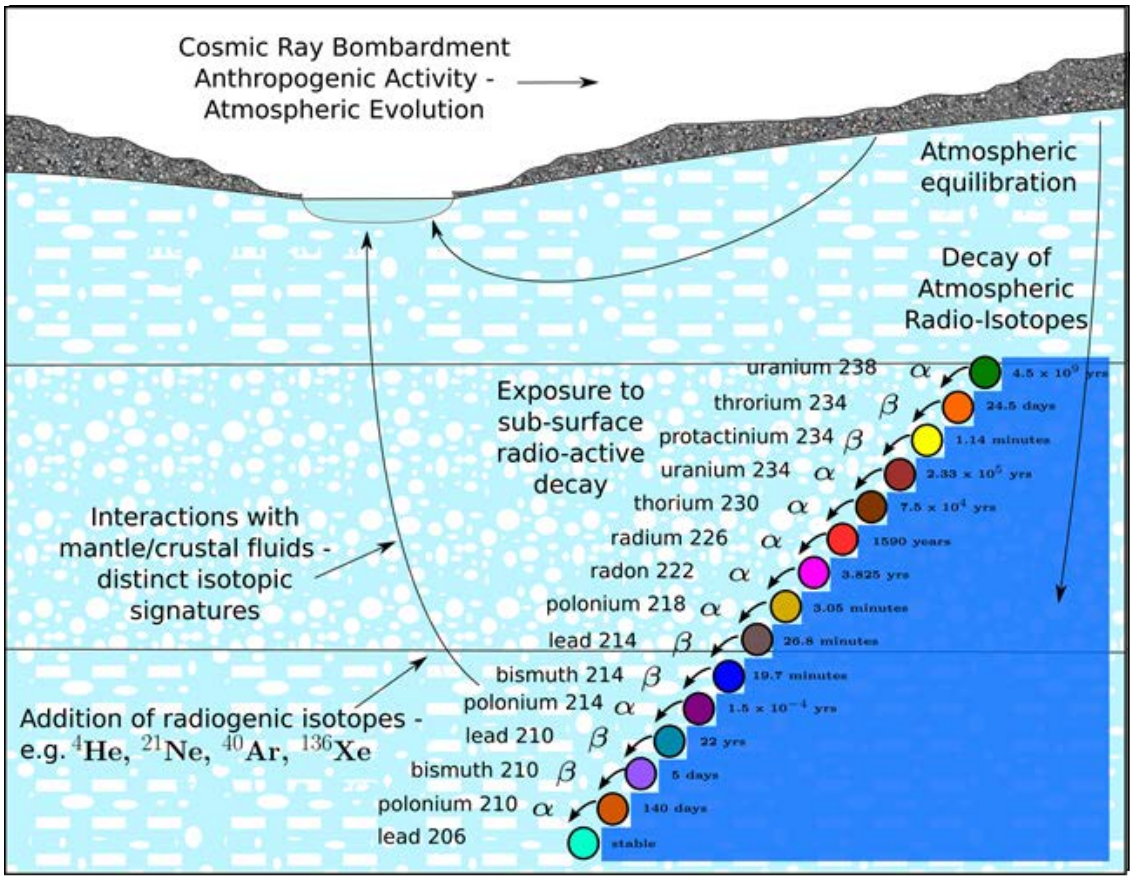
***Borehole designed to maximize likelihood of good samples***



# CB: Environmental Tracer Profiles

- **Vertical Profiles**
  - **Noble gases (He, Ne, etc.)**
  - **Stable water isotopes**
  - **Atmospheric radioisotope tracers (e.g., $^{81}Kr$, $^{129}I$, $^{36}Cl$)**
  - **$^{238}U/^{234}U$ ratios**
  - **$^{87}Sr/^{86}Sr$ ratios**
- **Long-Term Data**
  - **Water provenance**
  - **Flow mechanisms/isolation**

**Minerals → pores → fractures**
**(evaluate system "leakiness")**

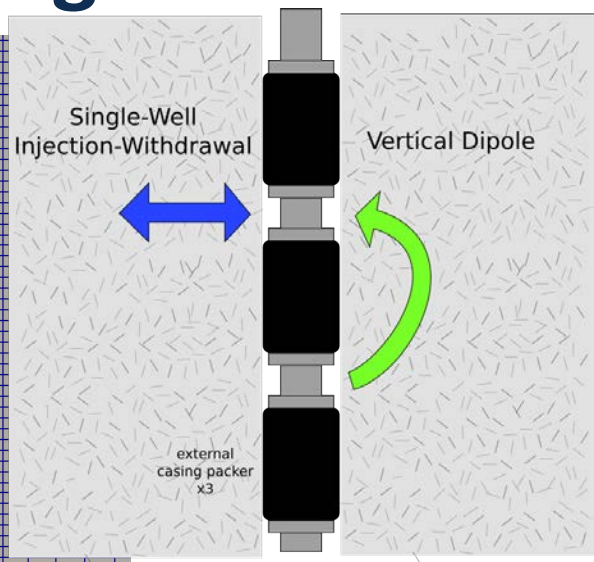



**Fluid Sample Quality + Quantity *will be a Focus!***

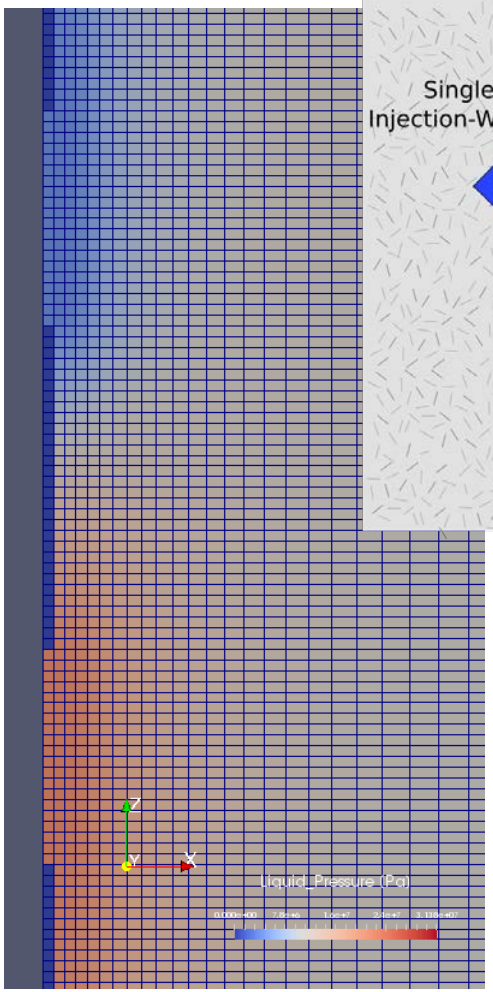
*Repeatability between* drill-stem testing, *packer & core samples?*

# CB: *In Situ* Hydrogeologic Testing

- **Hydrologic Property Profiles**
  - **Static formation pressure**
  - **Permeability / compressibility**
    - **Pumping/sampling in high k**
    - **Pulse testing in low k**
- **Borehole Tracer Tests**
  - **Single-well injection-withdrawal**
  - **Vertical dipole**
  - **Understand DRZ transport**
- **Hydraulic Fracturing Tests**
  - **$\sigma_h$ magnitude**
- **Borehole Heater Test**
  - **5-m long 5KW heater in crystalline basement**



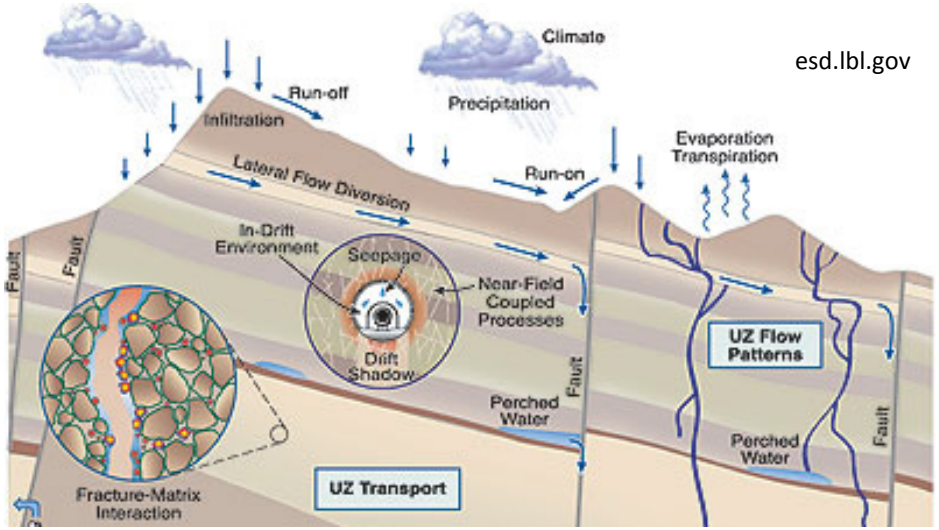

Tracer test concept




Test design modeling using PFLOTRAN

# DBD Characterization Approach

- **Borehole Characterization & Siting *vs.***
  - **Mined waste repositories**
    - **Less "site mapping"**
    - **Go/no go decision point**
    - **Single-phase fluid flow**
    - **Less steep pressure gradients**
  - **Oil/gas/mineral exploration**
    - **Low-permeability**
    - **Minimal mineralization**
    - **Avoid overpressure**
    - **Crystalline basement vs sedimentary rocks**
  - **Geothermal exploration**
    - **Low geothermal gradient**

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# Highlights

- **Deep Borehole Disposal Concept**
  - Robust isolation
  - Simple construction (for few boreholes)
  - Wide site availability
  - Single-Phase, Diffusion Dominated
  - Geological Issues?
    - Drill elsewhere vs. Engineer away
- **Deep Borehole Field Test (FY15-19)**
  - Drill two 5-km large-diameter boreholes
  - Demonstrate ability to
    - Characterize bedrock system (CB)
    - Emplace/retrieve test packages (FTB)
  - *Drilling to Begin Oct 2016!*

SAND2010-6048