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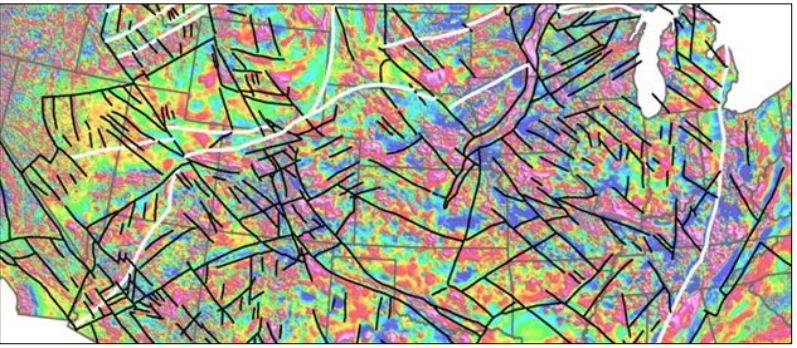

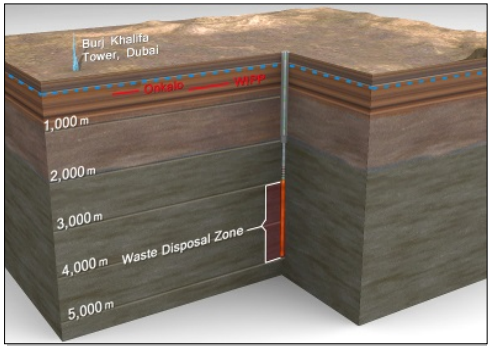

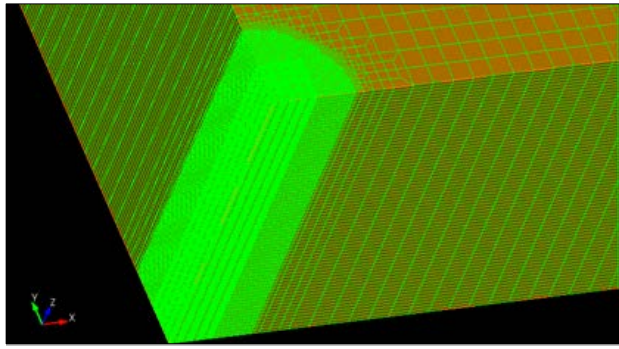

Deep Borehole Field Test Site Characterization

Kristopher L. Kuhlman

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Deep Borehole Field Test (DBFT)

- **Drill two 5-km boreholes**
  - **Characterization Borehole (CB): 21.6 cm [8.5”] diam. @ TD**
  - **Field Test Borehole (FTB): 43.2 cm [17”] diam. @ TD**

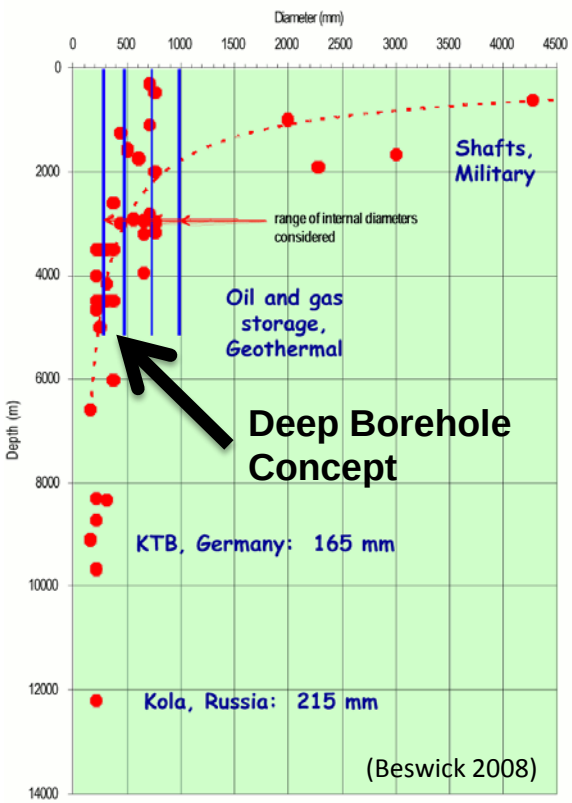
- **Prove ability to:**
  - **Drill deep, wide, straight borehole safely (CB + FTB)**
  - **Characterize bedrock (CB)**
  - **Test formations in situ (CB)**
  - **Collect geochemical profiles (CB)**
  - **Emplace/retrieve surrogate canisters (FTB only)**

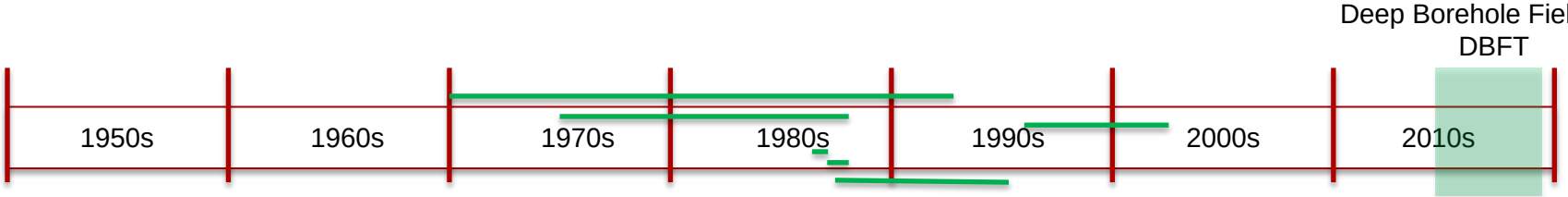
DBFT FY15

- **Sandia**
  - **Selection:** **Dave Sassani**
  - **Characterization:** **Kris Kuhlman**
  - **Engineering Demo:** **Ernie Hardin**
  - **Project Coordination:** **Geoff Freeze**
- **Berkeley**
  - **Assistance on characterization (Birkholzer, Daley & Freifeld)**
- **Deliverables**
  - **June 2015**
    - *Deep Borehole Field Test: Characterization Borehole Science Objectives*
  - **September 2015**
    - **Level-2:** M2FT-15SN0817081
    - *Conceptual Design and Requirements for Characterization and Field Test Boreholes*

Deep Continental Drilling Experience

Name	Location	Years	Depth [km]	Diam. [in]	Purpose
Kola SG-3	NW USSR	1970-1992	12.2	8½	Geologic Exploration + Technology Development
Fenton Hill (3)	New Mexico	1975-1987	3, 4.2, 4.6	8¾, 9⅞	Enhanced Geothermal
Gravberg	Central Sweden	1986-1987	6.6	6½	Gas Wildcat in Siljan Impact Structure
Cajon Pass	California	1987-1988	3.5	6¼	Geomechanics near San Andreas Fault
KTB (2)	SE Germany	1987-1994	4, 9.1	6, 6½	Geologic Exploration + Technology Development
Soultz-sous-Forêts GPK (3)	NE France	1995-2003	5.1, 5.1, 5.3	9⅝	Enhanced Geothermal

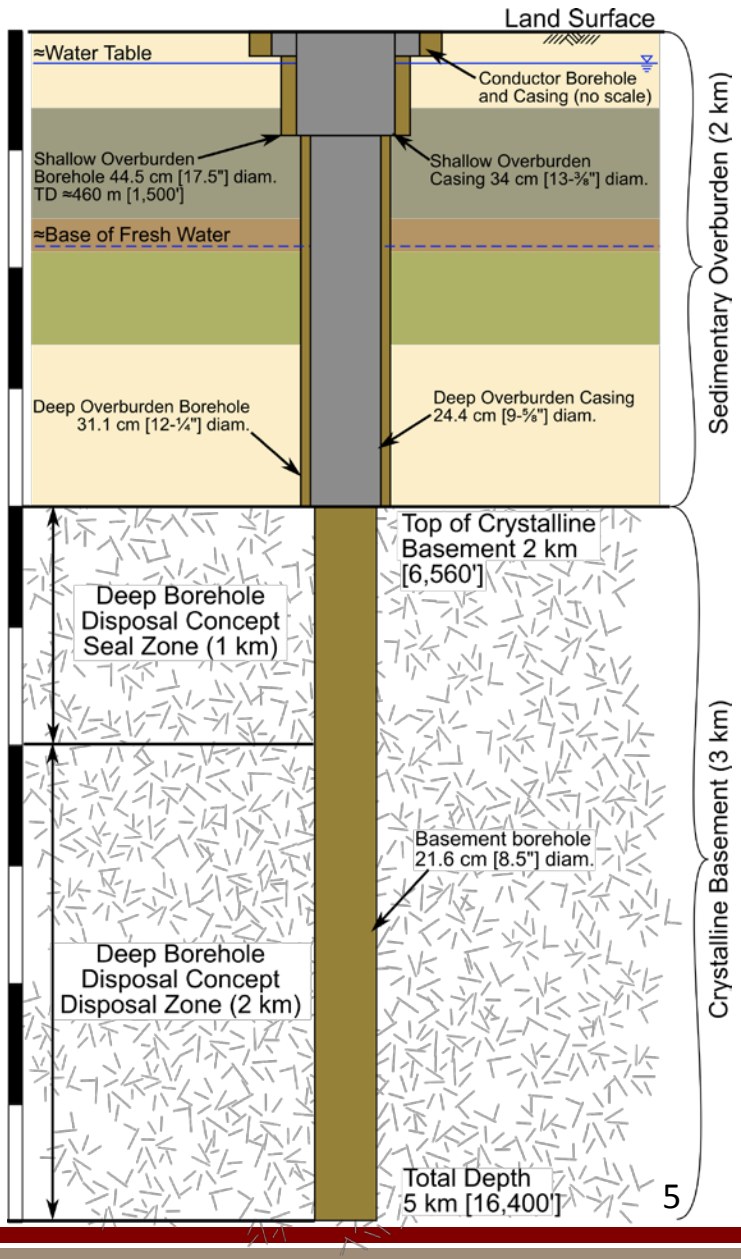




Characterization Borehole

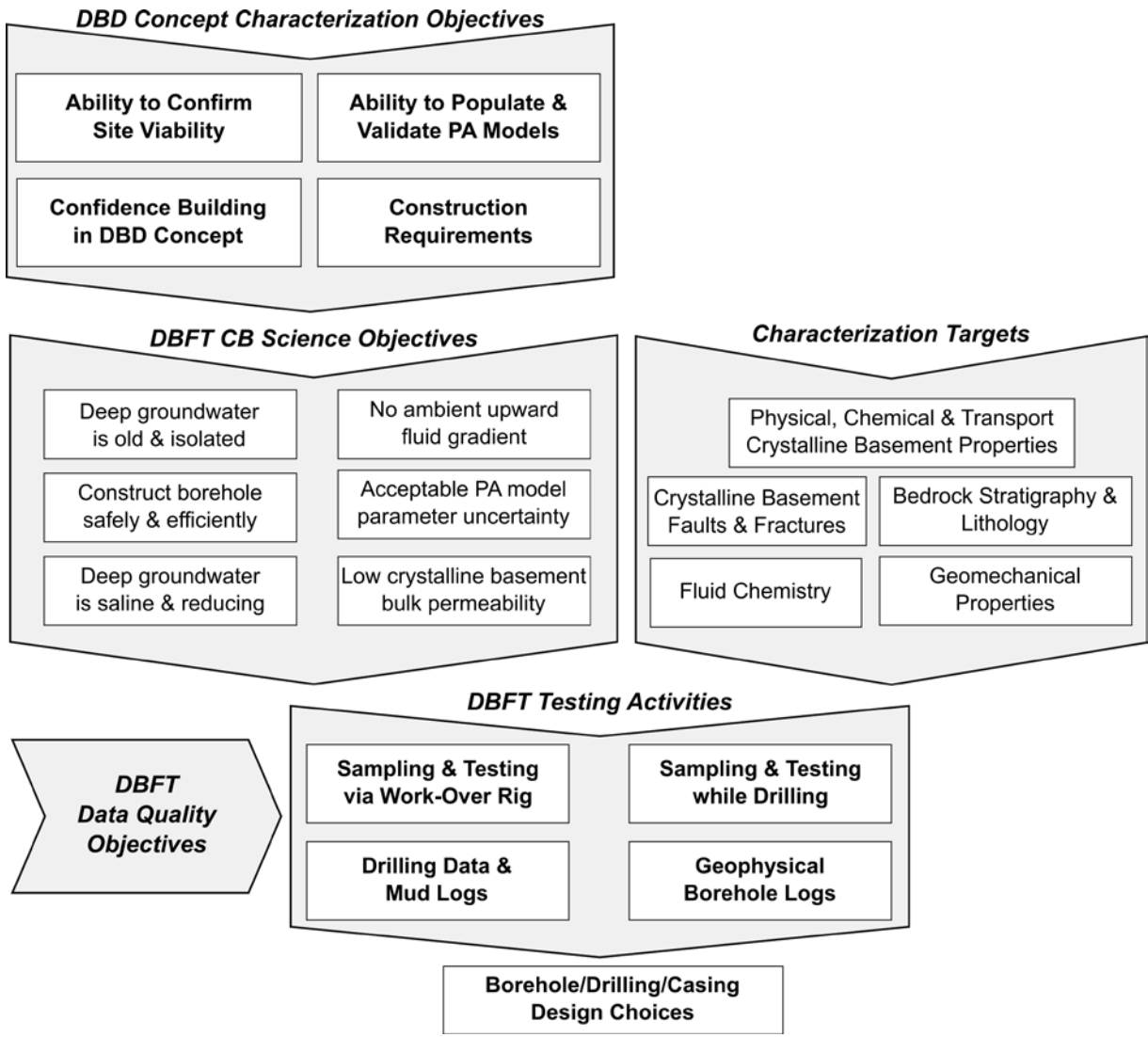
- **Drill/case sedimentary section**
  - **Minimal testing (not DBFT focus)**
- **Drill crystalline basement section**
  - **Core 150 m over 3 km (5%)**
  - **Hydrofracture stress tests**
  - **Borehole geophysics**
  - **Basement production log**
  - **Pore/fracture water samples**
- **Packer tool via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

Borehole designed to maximize likelihood of good samples



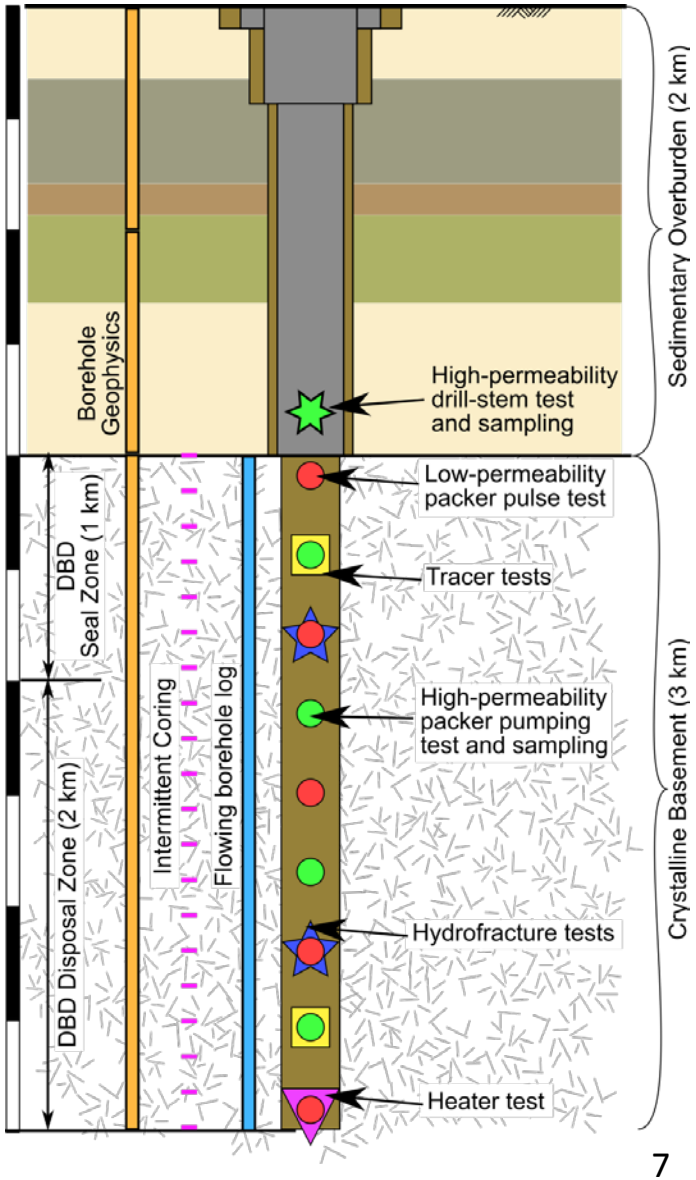
Characterization Targets/Methods

- **Field Test Drivers**
  - **Why?**
- **Science Objectives**
  - **What are goals?**
- **Char. Targets**
  - **What can we measure?**
- **Field Activities**
  - **What will we do?**
- **Borehole Design**



CB: Profiles

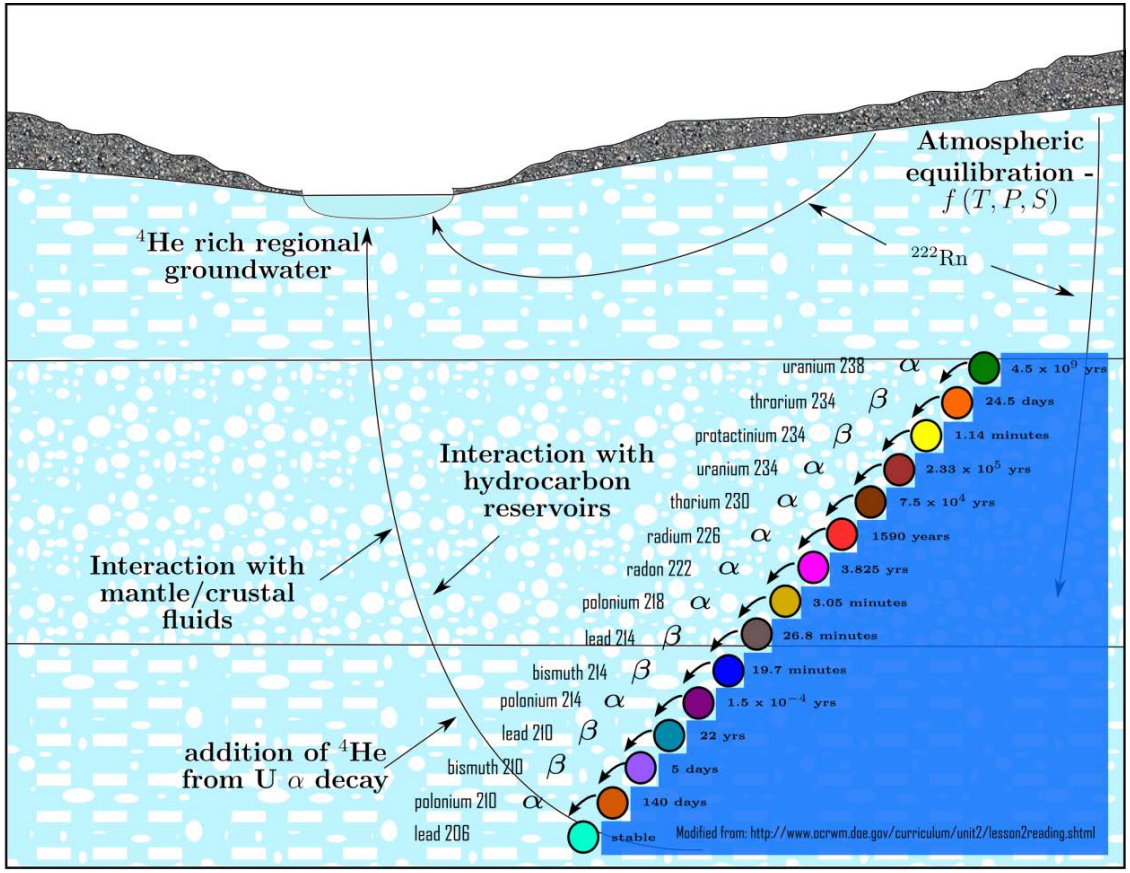
- Borehole Geophysics
- Coring/Cuttings/Rock Flour
- Sample-based Profiles
  - Fluid density/temperature/major ions
  - Pumped samples from high-*k* regions
  - Samples from cores in low-*k* regions
- Drilling Parameters Logging
  - Mud fluids/solids/dissolved gases
  - Torque, weight-on-bit, etc.
- Testing-Based Profiles
  - Static formation pressure
  - Formation hydraulic/transport properties
  - *In situ* stress (hydrofrac + breakouts)



CB: Environmental Tracers

- **Vertical Profiles**
  - **Noble gases (He + Ne)**
  - **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**

Minerals → pores → fractures

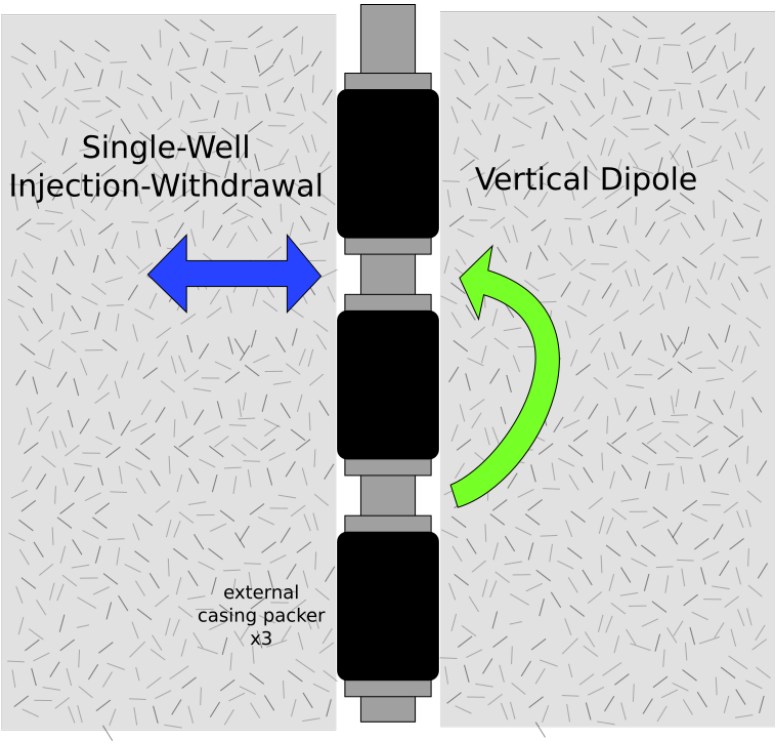


Fluid Sample Quality + Quantity *will be Very Important!*

Repeatability between DST, packer & core samples?

CB: 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 transport pathways**
- **Hydraulic Fracturing Tests**
  - **σ_h magnitude**
- **Borehole Heater Test**
  - **Surrogate canister with heater**



Deep Borehole Field Test

- **Characterization & siting are *different from*:**
  - **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**
    - **Avoid mineralization**
    - **Avoid overpressure**
  - **Geothermal exploration**
    - **Low geothermal gradient**