SAND2017-0201C

U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Deep Borehole Field Test Overview

David C. Sassani
Sandia National Laboratories
Used Fuel Disposition R&D Campaign

The Institute for Nuclear Materials Management
32nd Spent Fuel Management Seminar
Washington, DC
January 10 - 12, 2017

Sandia National Laboratories

Sandia National Laboratories is a multi-mission 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. SAND2017-XXXX C

Presentation Overview

- **Deep Borehole Field Test (DBFT) Background**
  - The Deep Borehole Disposal (DBD) Concept
    - Feasibility is being evaluated
  - DBFT Objectives – Science and Data to Evaluate DBD Concept
- **Geoscience Guidelines for DBFT Site**
- **Planned Testing**
- **Status of US DOE Program**
- **Summary and Conclusions**

Deep Borehole Disposal (DBD) Concept

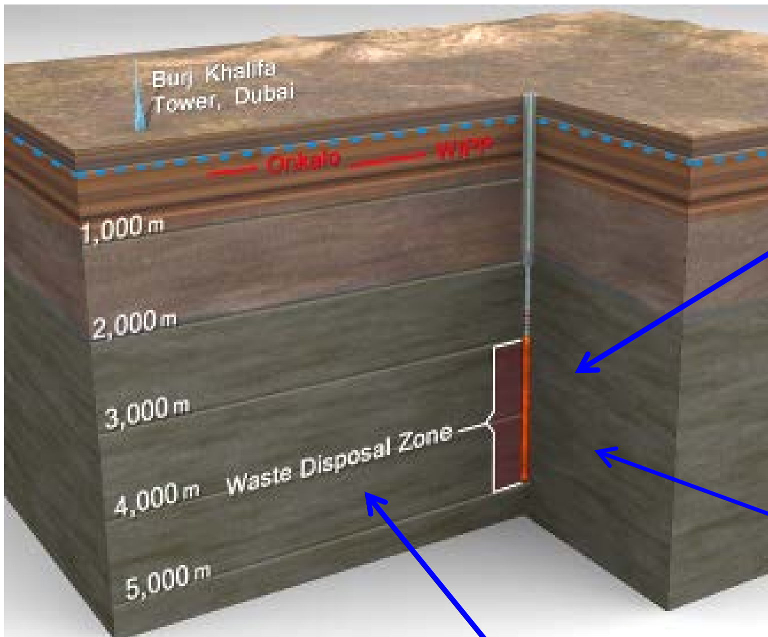
- **Deep borehole disposal of high-level radioactive waste has been considered in the U.S. and elsewhere since the 1950s and has been periodically studied since the 1970s**
- **Current DBD concept consists of drilling a borehole (or array of boreholes) into crystalline basement rock**
  - Total depth about 5,000 m depth
  - Lower 3000 m in crystalline basement
  - Waste canisters would be emplaced in the lower 2,000 meters
  - Upper crystalline basement portion would be sealed with compacted bentonite clay, cement plugs, and cemented backfill
    - At least 1000 m
  - Upper borehole filled/sealed

Why Deep Borehole Disposal?

- **Potential for Robust Isolation**
- **Gives DOE the Flexibility to Consider Options for Disposal of Smaller Waste Forms in Deep Boreholes**
  - Potentially earlier disposal of some wastes than might be possible in a mined repository
  - Possible reduced costs associated with projected treatments of some wastes
- **Several DOE-managed Small Waste Forms are Potential Candidates for Deep Borehole Disposal (SNL 2014)**
  - Cesium and strontium capsules. 1,936 cesium and strontium capsules stored at the Hanford Site
  - Untreated calcine HLW currently stored at INL in sets of stainless steel bins within concrete vaults
  - Salt wastes from electrometallurgical treatment of sodium-bonded fuels could be packaged in small canisters as they are produced
  - Some DOE-managed SNF currently stored in pools at INL and SRS

DBD Concept – Safety and Feasibility Considerations

Long-Term Waste Isolation (hydrogeochemical characteristics)



Waste emplacement is deep in crystalline basement

- At least 1,000 m of crystalline rock (seal zone) overlying the waste disposal zone
- Crystalline basement within 2,000 m of the surface is common in many stable continental regions

Crystalline basement can have very low permeability

- limits flow and transport

Deep groundwater in the crystalline basement:

- Can have very long residence times – isolated from shallow groundwater
- Can be highly saline and geochemically reducing – enhances the sorption and limits solubility of many radionuclides
- Can have density stratification (saline groundwater underlying fresh groundwater) – opposes thermally-induced upward groundwater convection

Deep Borehole Field Test (DBFT)

- **Assess DBD Feasibility Via Field Study of Site and Handling**
  - Five (5) year project
- **Construct Two 5-km Boreholes**
  - Characterization Borehole (CB): 21.6 cm [8.5”] @ Total Depth
  - Field Test Borehole (FTB): 43.2 cm [17”] @ Total Depth
- **Evaluate our Ability to:**
  - Drill deep, wide, straight in crystalline rocks (CB + FTB)
  - Characterize bedrock via geophysics (CB)
  - Conduct tests in basement ≤150^{o}C & 50 MPa (CB)
  - Collect geochemical profiles (CB)
  - Emplace/retrieve surrogate waste packages (FTB)

DBFT Technical Team Members

- **DOE NE-81**
  - Tim Gunter, Federal Program Manager
  - Mark Tynan, Program Technical Lead
- **Sandia National Laboratories – DBFT Project Technical Lead**
  - Bob MacKinnon, Manager
  - Geoff Freeze, Project Lead and Safety Assessment
  - David Sassani, Site Evaluation and Data Integration Lead
  - Kris Kuhlman, Site Characterization/Testing Lead
  - Ernie Hardin, Design Engineering Handling/Emplacement Lead
- **DBFT Laboratory Participants**
  - LANL – Regional geology, geoscience, site characterization
  - LBNL – Geoscience, site characterization
  - ORNL – Surface characteristics/hazard analyses
  - INL – Web visualization/interface for geoscience data
  - PNNL – Characterization design support

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

Deep Borehole Field Test Objectives

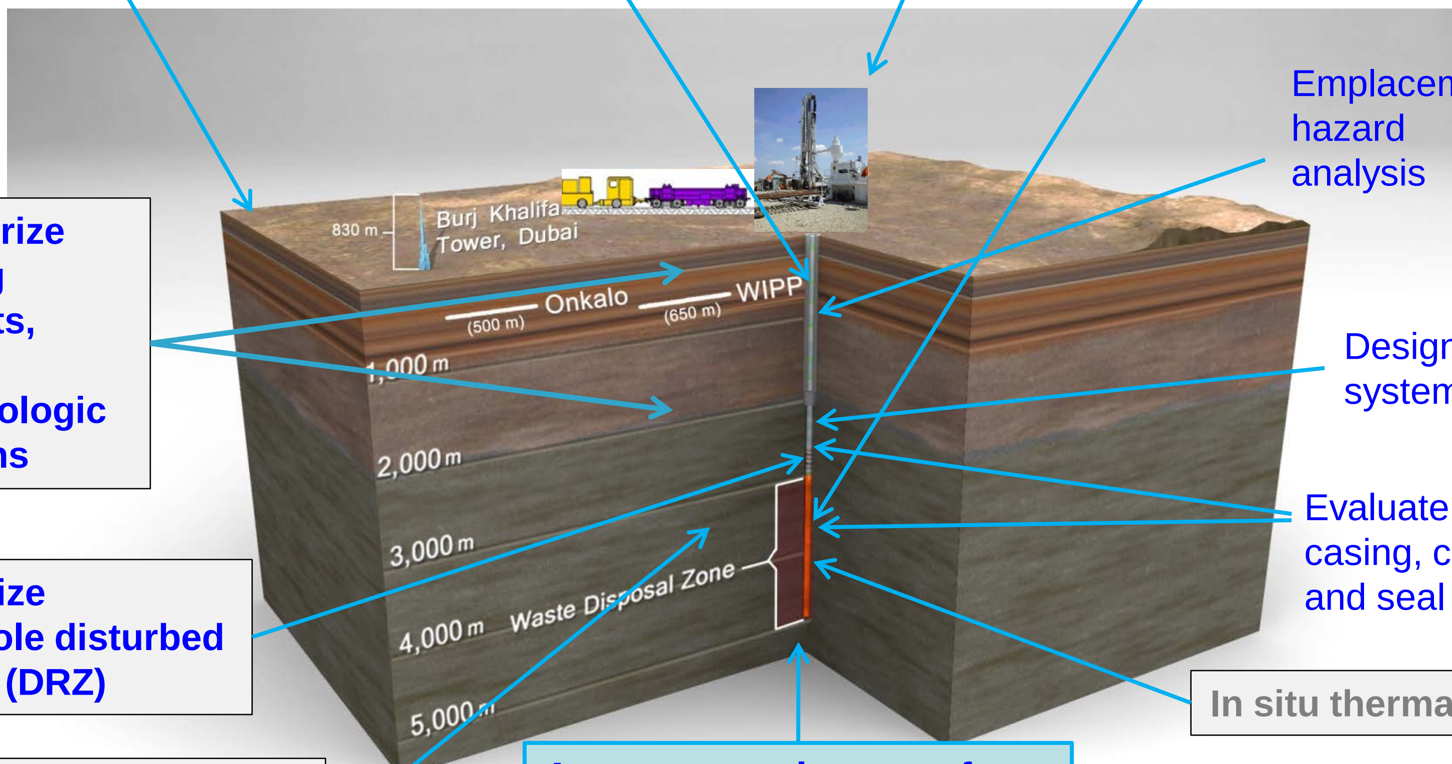
Evaluate site

Design and construct characterization borehole then field test borehole

Develop and test systems for handling, emplacing, and retrieving WPs

Design and test WPs

Emplacement hazard analysis



Characterize overlying sediments, fluids, and hydrologic conditions

Design seal system

Evaluate WP, WF, casing, cement, and seal materials

Characterize the borehole disturbed rock zone (DRZ)

In situ thermal test

Characterize crystalline basement, fluids, and hydrologic conditions

Assess post-closure safety
Synthesize field test activities, test results, and analyses into a comprehensive evaluation of concept feasibility

No radioactive waste will be used in conjunction with the DBFT activities (DOE RFP 2016).

U.S. DEPARTMENT OF ENERGY

Nuclear Energy

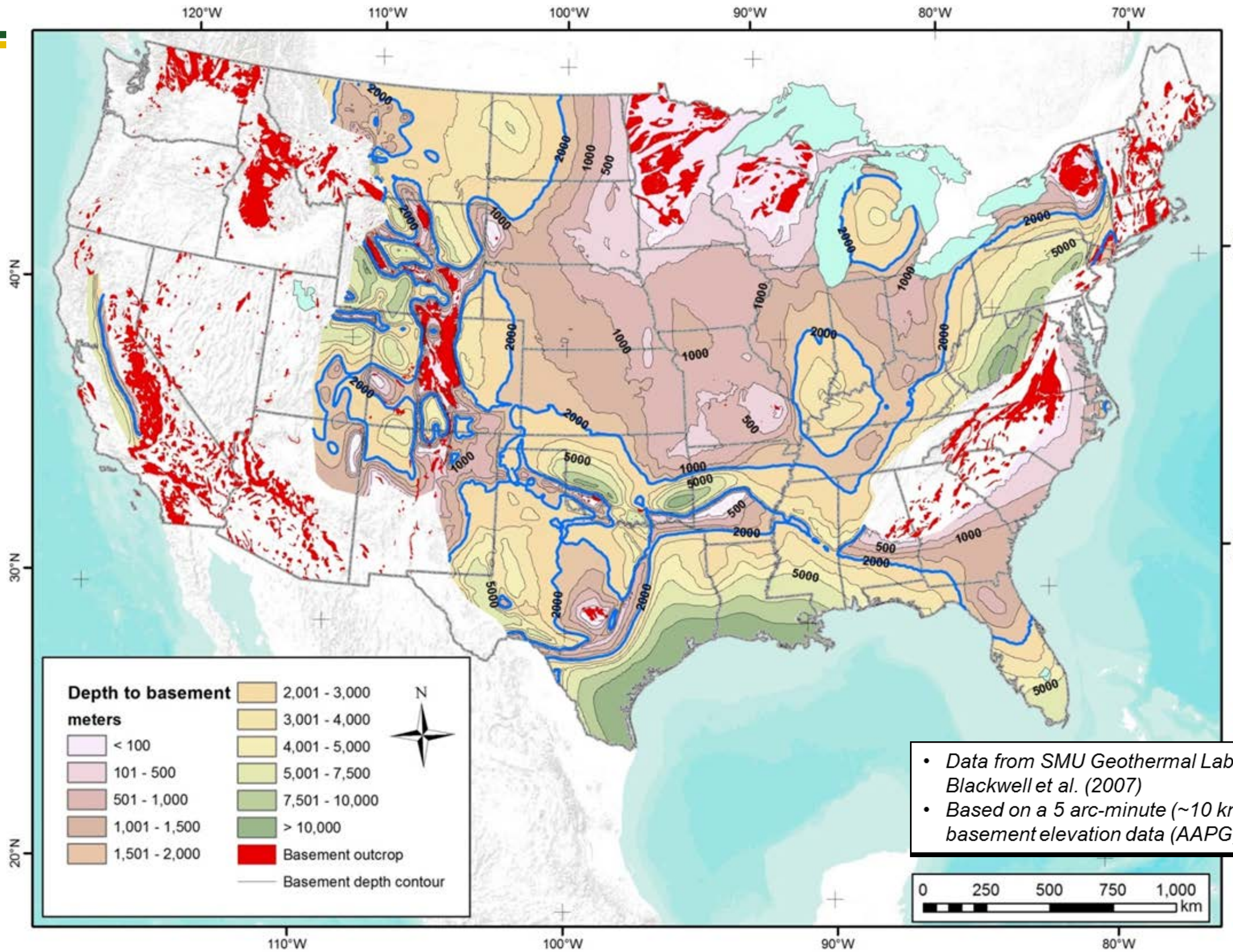
DBFT Site Geoscience Guidelines Considerations

- **Crystalline Basement**
  - Depth
  - Rock Fabric & Stress State
  - Regional Structure(s)
  - Hydrology and Geochemistry
- **Heat Flow**
- **Recent Seismicity/Volcanism**
- **Resources**
- **Anthropogenic Contamination**

U.S. DEPARTMENT OF ENERGY

Nuclear Energy

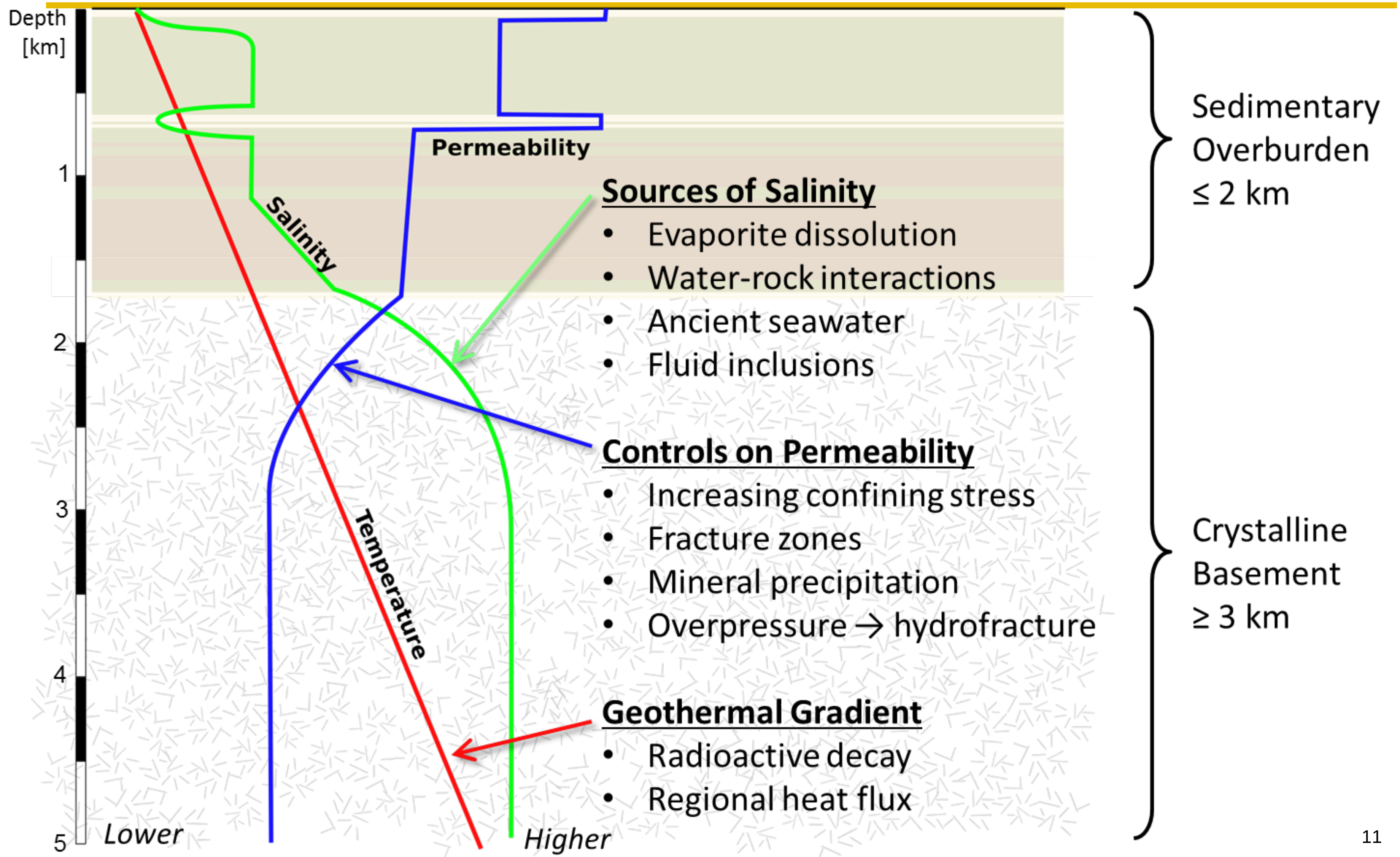
Depth to Basement – National Scale



- *Data from SMU Geothermal Laboratory - Blackwell et al. (2007)*
- *Based on a 5 arc-minute (~10 km) grid spacing of basement elevation data (AAPG, 1978)*

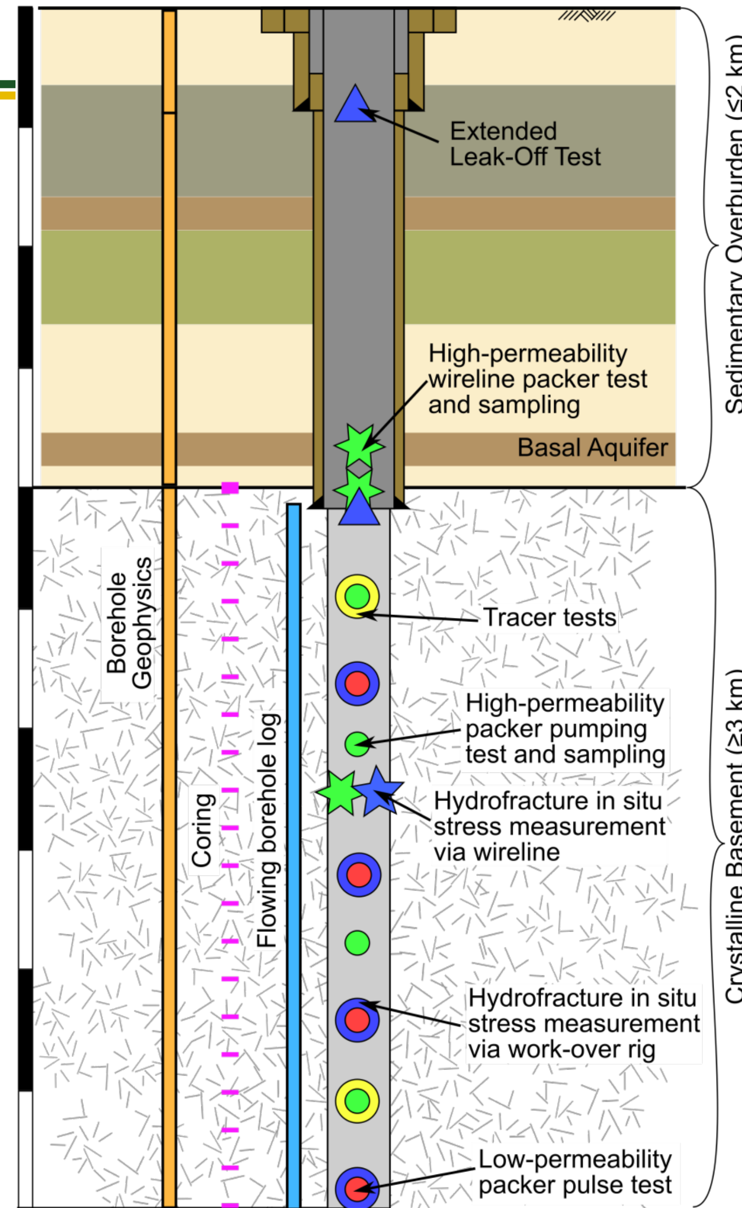
Distribution of crystalline basement at a depth of less than 2 km (tan shading) and granitic outcrop (red) in the contiguous US (from Figure 3-2 in Perry et al., 2015)

Deep Borehole Conceptual Profiles



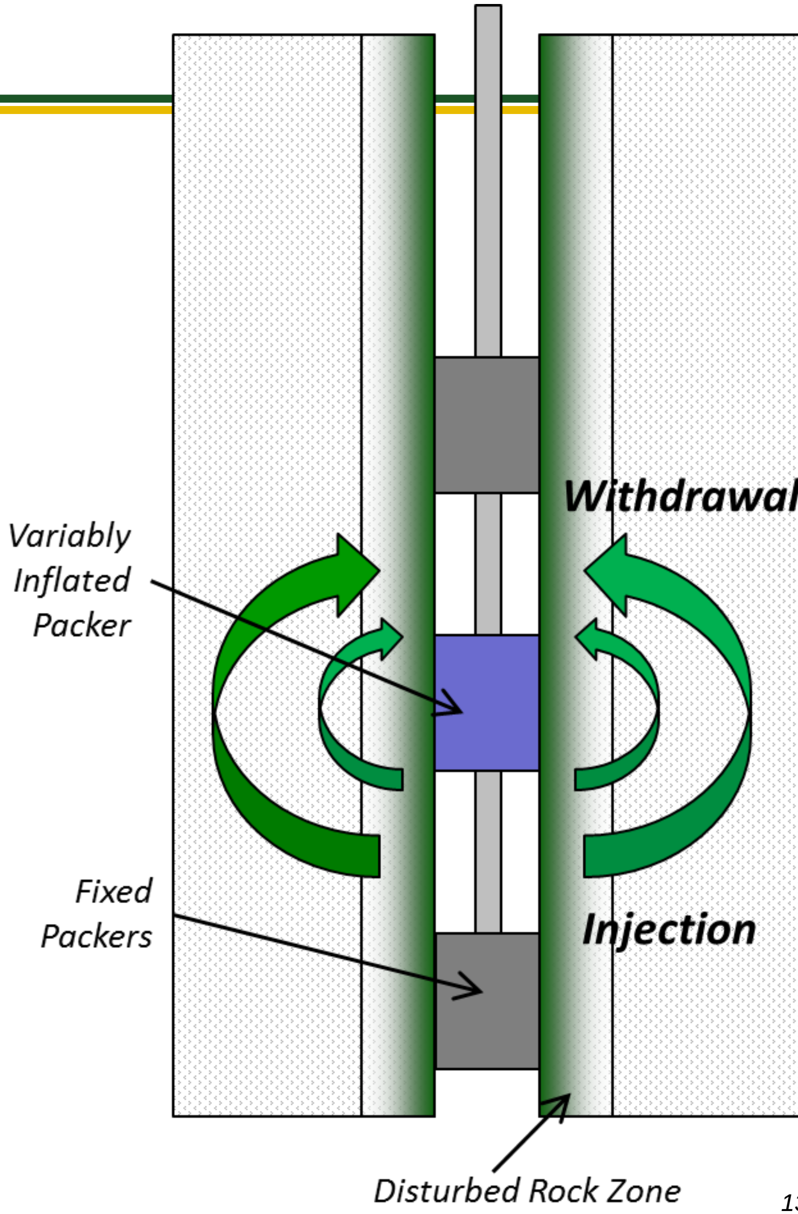
CB Sampling Profiles

- **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 & quartz
  - Stable water isotopes



CB *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 fractured intervals

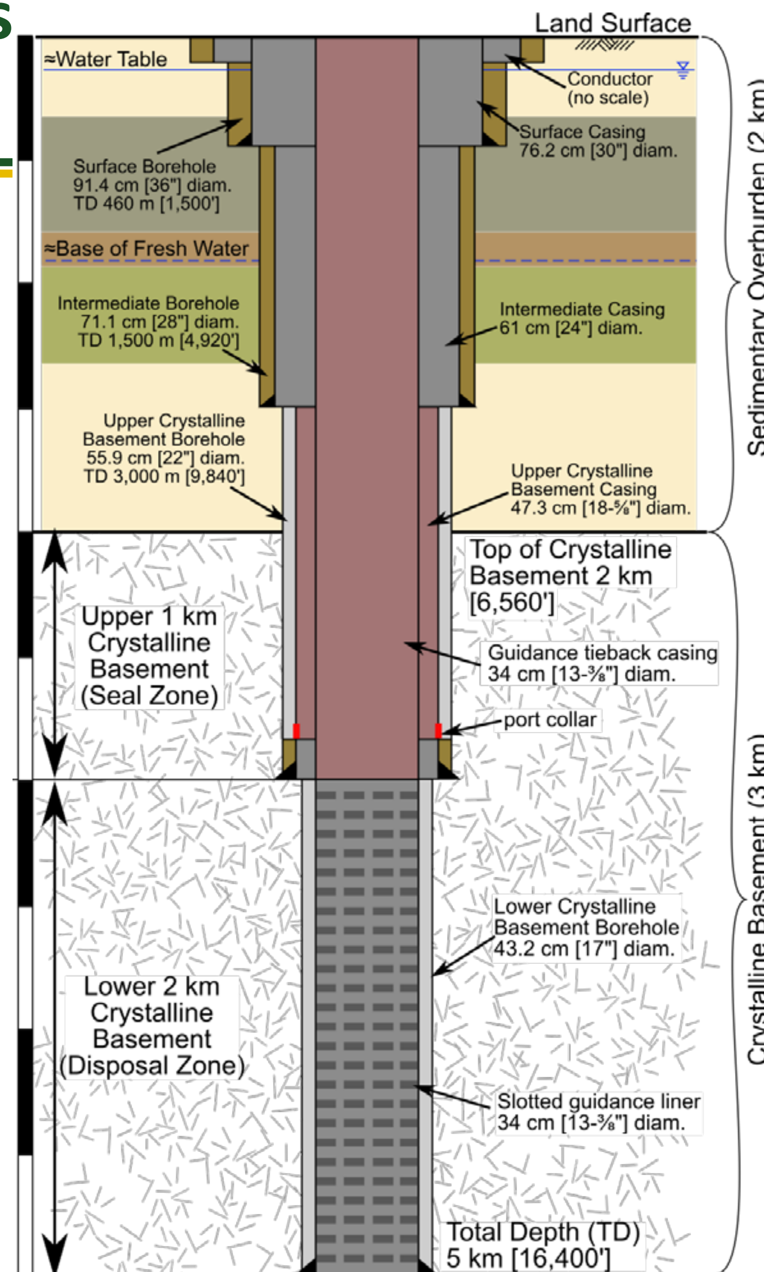


U.S. DEPARTMENT OF ENERGY

Nuclear Energy

FTB Objectives

- **If CB Results are Favorable, then Drill and Complete FTB**
- **Reflect DBD reference design diameter/plan (17-inch diameter)**
  - 17-inch diameter at a few km depth in hard rock is not uncommon for geothermal
- **Evaluate emplacement/removal of surrogate canisters**
- **Evaluate casing removal**



DOE Acquisition of Site and Services

- **US DOE RFP (Solicitation Number DE-SOL-0010181)**
  - Pre-solicitation notice posted on August 5, 2016
  - Final RFP posted on FedBizOps on August 22, 2016
  - Proposals received October 24, 2016
- **DOE Announced Contract Awards December 19, 2016**
  - AECOM - exploring a site in Texas
  - ENERCON - exploring a site in New Mexico
  - TerranearPMC - exploring a site in New Mexico
  - RE/SPEC - exploring a site in South Dakota
- **Contracts have Phased Approach**
  - Emphasizes the importance of engaging the local community in the project

U.S. DEPARTMENT OF ENERGY

Nuclear Energy

Summary and Conclusions

- **Many Sites within U.S. with Functional Geology**
  - Multifaceted objectives of DBFT provide opportunities for success
- **Choosing Site will be Based on Uncertain Geologic Information**
  - Generally regions lacking exploration
  - Any Site will have its own geologic challenges
- **Will Provide Substantial Direct Data and Understanding**
  - Characterization methods in deep crystalline basement
  - Feasibility of implementing reference design
- **US DOE Approach – Explicit and Early Community Outreach/Involvement**