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Panel #6 Multiple Barriers: Waste Forms and Canister Materials

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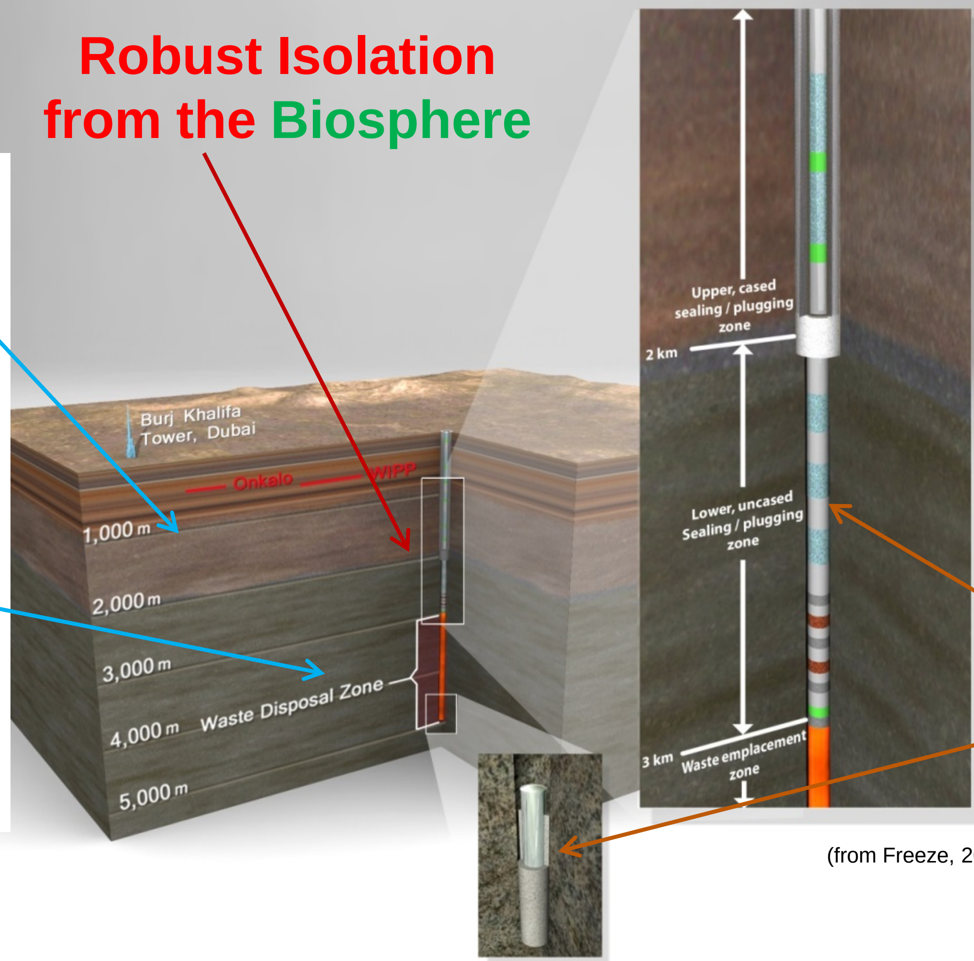
Deep Borehole Disposal Post-Closure Conceptual Model – Components

Robust Isolation from the Biosphere



(from Freeze, 2015)

Natural System

- Overlying Sediments
- Crystalline Basement
  - *Low permeability and long residence time*
  - *Density stratification of brine opposes upward convection*
  - *Geochemically reducing conditions limit the solubility and enhance the sorption of many radionuclides*

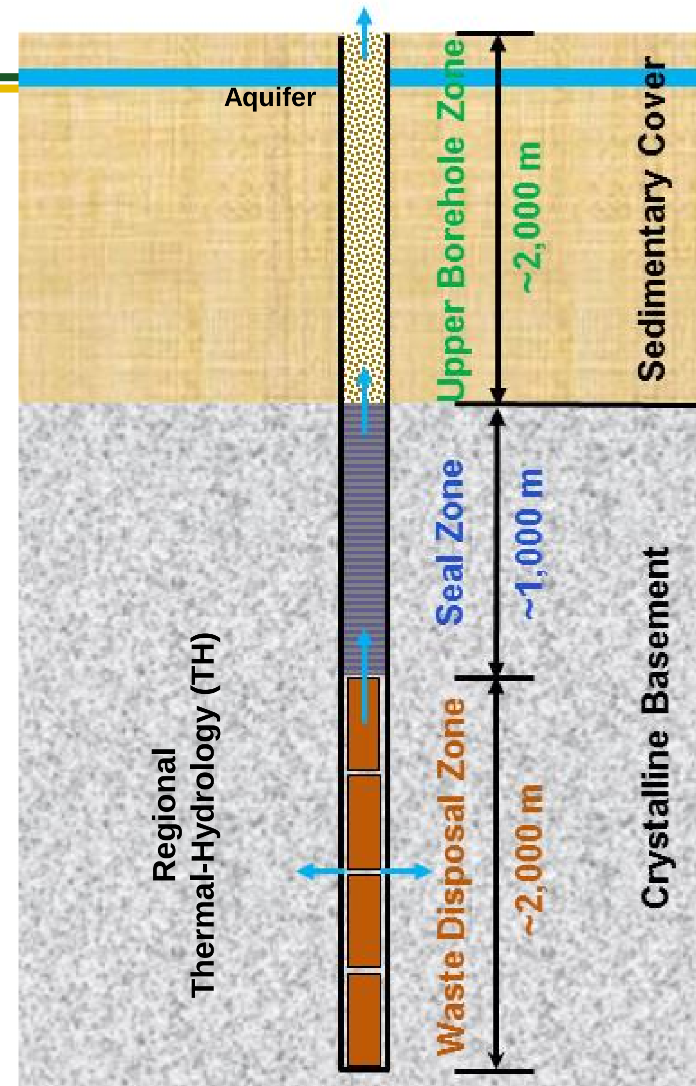
Engineered Barriers

- Borehole seals (and disturbed rock zone)
- Waste forms
- Waste packages

Deep Borehole Disposal Conceptual Model

Overview: Single Borehole Undisturbed Scenario

- **Waste Package**
  - Provides structural integrity for emplacement/removal operational protection
    - assumed to rapidly degrade after emplacement seal
- **Inventory / Waste Form**
  - DOE-managed High Level Waste (HLW)
    - Cesium/Strontium (CsCl)/(SrF_2) Capsules
  - *Previous* - Commercial Spent Nuclear Fuel (SNF)
- **Post-Closure Release Pathways**
  - Undisturbed
    - Up borehole through seals/disturbed rock zone
      - Seals represent multiple barrier with geology
    - To host rock surrounding disposal zone
      - High-permeability pathway to shallow groundwater
- **Biosphere (Dose)**
    - Subsurface release to aquifer
    - Pumping from aquifer to surface receptor
- **Primary Barrier is Geologic System**
  - Isolated, reducing, low permeability
  - Long transport pathway, likely diffusive



(from Freeze, 2015)

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Canister/Package Materials and Performance Goals

Conceptual Test Packages for DBFT

- Direct use of drill pipe steel (e.g., small test package overpack)
  - Material: alloy steel; hardened/tempered, 110 ksi yield (API* P110)
- Possible alternative - stronger material for larger safety factor
  - More difficult to work

*American Petroleum Institute

Universal Canister Materials

- Stainless steel (316-L)
- Overpack for disposal - perhaps like test canister

Performance Goals for Disposal

- Canister/package structural stability for safe emplacement of waste forms
  - Non crushing in higher-pressure environment
  - Strength to support package weights above (bridge plugs between multiple packages)
- After emplacement and sealing
  - Lifetime assumed to be ~decade(s)
  - No postclosure performance credit taken in previous analyses

Wastes Being Considered for Deep Borehole Disposal and Performance Goals

- **DOE-Managed Small Waste Forms are Potential Candidates for DBD (SNL 2014)**
  - Cesium (CsCl) and strontium (SrF_2) capsules stored at the Hanford Site
    - Reasonably well understood (straightforward) materials
  - 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 smaller DOE-managed SNF
    - Currently stored in pools at Idaho National Laboratory and Savannah River Site
  - Vitrified HLW that has not yet been made
    - Would need to be packaged for deep borehole disposal
- **Performance Goals Driven Primarily by Natural System**
  - Degradation rates of waste forms are not primary barrier (package – no credit taken)
  - Reliance more directly on geologic conditions in crystalline basement
    - Low solubility limits on radionuclide concentrations
    - Slow transport due to diffusive flux and interaction with seals materials
      - Transport along borehole retarded by seals retarding radionuclides
      - low permeability and sorptive/reactive

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DBD Conceptual Model – Undisturbed Scenario Waste Form Concepts

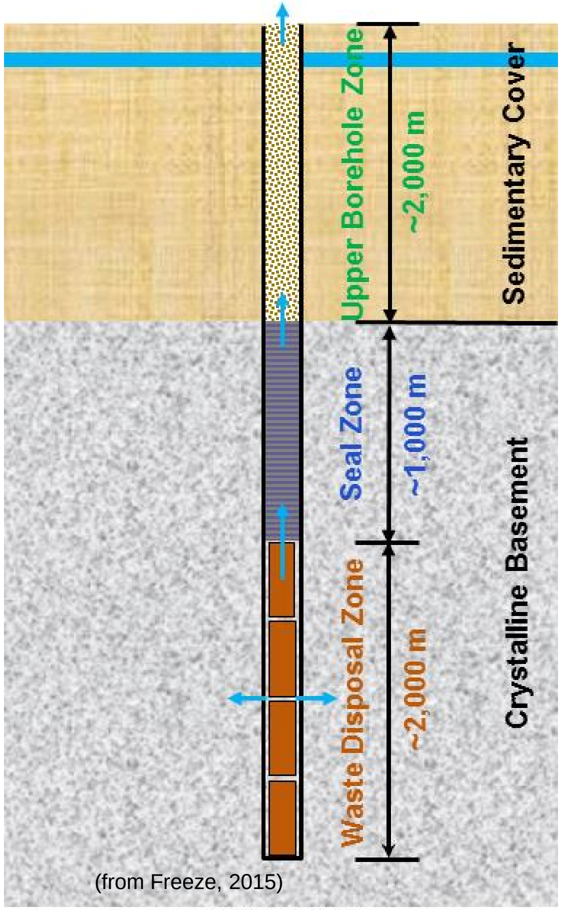
Inventory and Waste Form Degradation Rates

Previous Performance Assessment (PA) Work

- 400 assemblies stacked in a 2,000 m zone
  - Radionuclide inventory and thermal output (Carter et al. 2012)
  - Waste form fractional degradation rate
    - slower = 1×10^{-7} yr^{-1}
      - » mass release: 50% by 4,800,000 yrs; 76% by 10,000,000 yrs
    - faster = 2×10^{-5} yr^{-1}
      - » mass release: 50% by 35,000 yrs; 99.9% by 350,000 yrs

Current/Future PA Work

- 1936 CsCl/SrF_2 capsules stacked in 1,300 m zone
  - Radionuclide inventory and thermal output from 1335 CsCl capsules and 601 SrF_2 capsules (SNL, 2014)
  - Degradation rates appears to be rapid – CsCl (SrF_2 solubility limit)
  - Cs^+, Sr^{2+} aqueous ions interaction with clays/zeolites (seals)



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Solubility Limits – Low for Redox Sensitive Radioelements

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