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# Siting Guidelines for a Deep Borehole Disposal Facility

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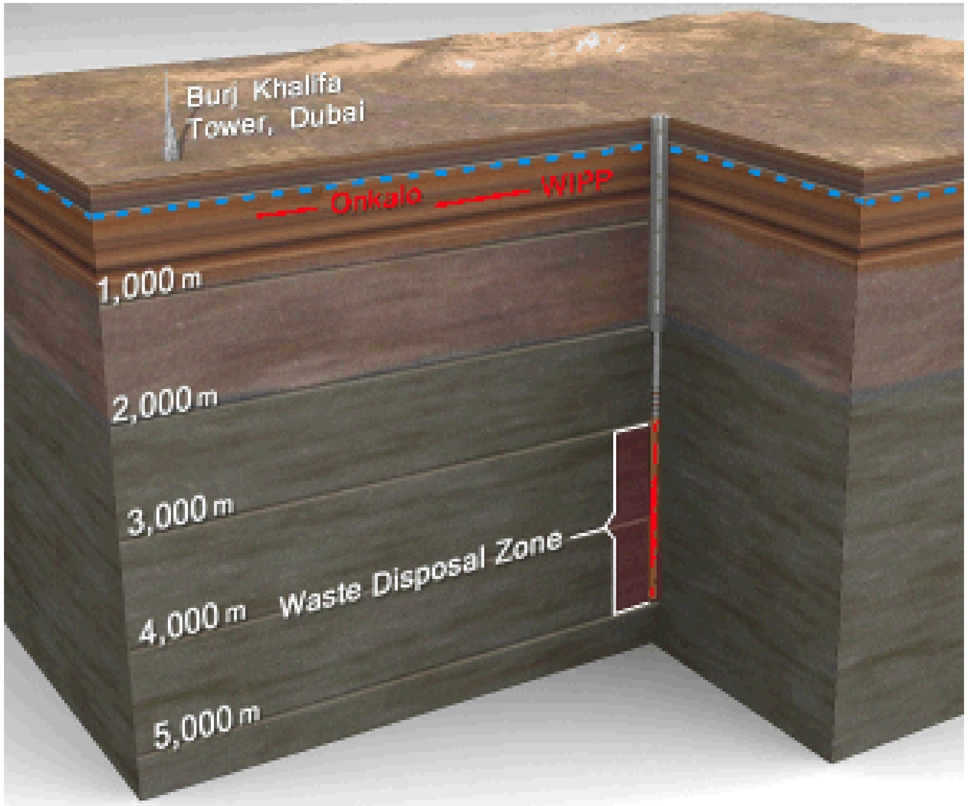
# Outline

- **Deep Borehole Disposal Concept**
  - Safety and Viability
  - Deep Borehole Field Test
- **Siting Factors**
  - Technical
  - Logistical
  - Sociopolitical
- **Summary and Conclusions**

# Deep Borehole Disposal Concept

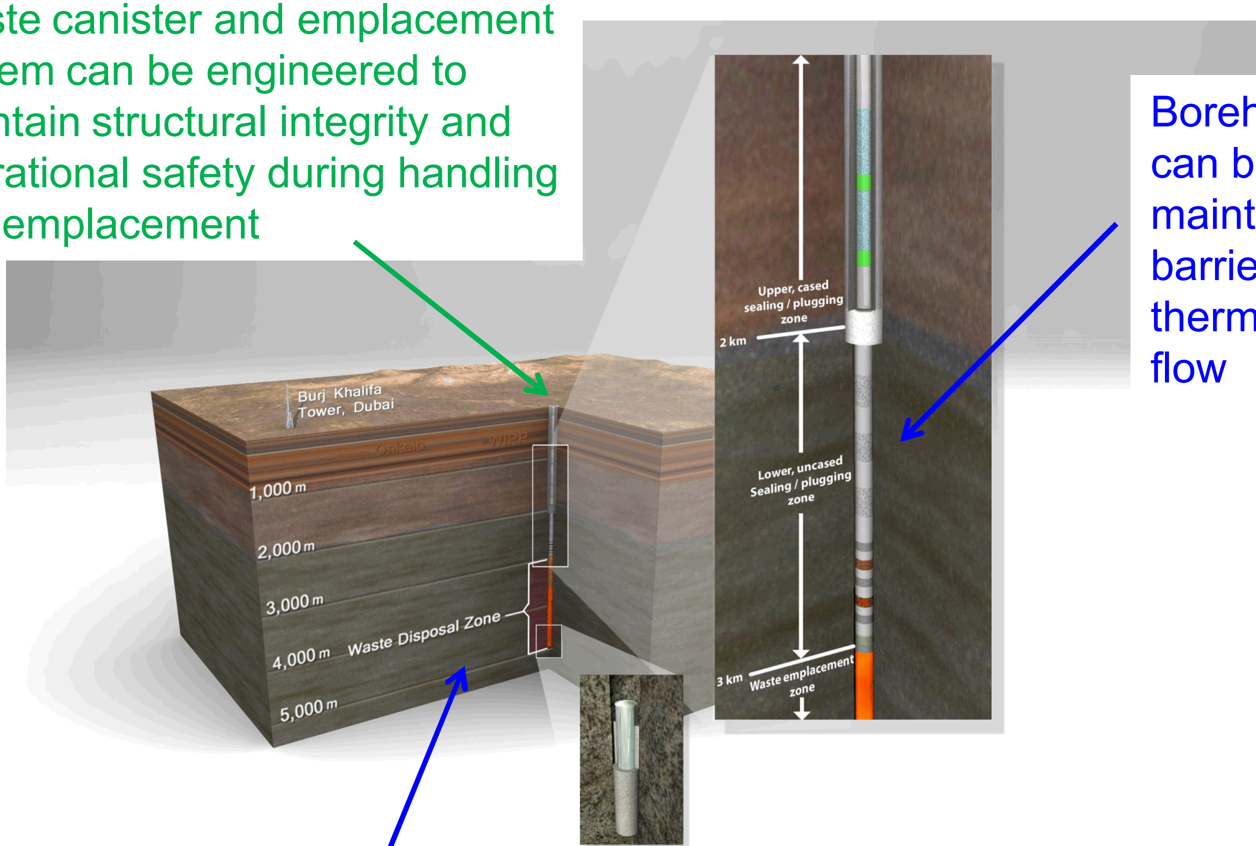
- **5,000 m deep borehole(s) in crystalline basement rock, well below fresh groundwater resources**
  - Waste canisters in bottom 2,000 m
  - Seals in upper 3,000 m

- **Bottom hole diameter**
  - 17 in. for bulk waste forms or SNF/HLW
  - 8.5 in. for smaller DOE-managed waste forms



# Deep Borehole Disposal Concept –
# Safety and Viability (Operational and Postclosure)

Waste canister and emplacement system can be engineered to maintain structural integrity and operational safety during handling and emplacement

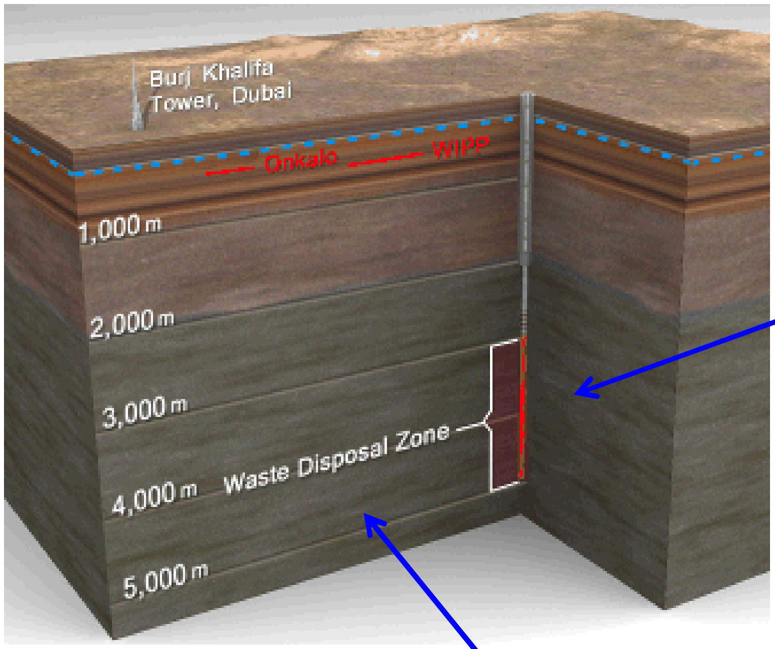



Borehole seals (and DRZ) can be engineered/evolve to maintain a low-permeability barrier over the period of thermally-induced upward flow

Deep crystalline rocks typically have low permeability and lack hydraulic connection to shallow groundwater

# Deep Borehole Disposal Concept – Safety and Viability Considerations

## Long-Term Waste Isolation (hydrogeochemical considerations)




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

Deep groundwater in the crystalline basement:

- has very long residence times – isolated from shallow groundwater
- has high salinity and is geochemically reducing – limits the solubility and enhances the sorption of many radionuclides in wastes
- exhibits density stratification (saline groundwater underlying fresh groundwater) – opposes thermally-induced upward groundwater convection

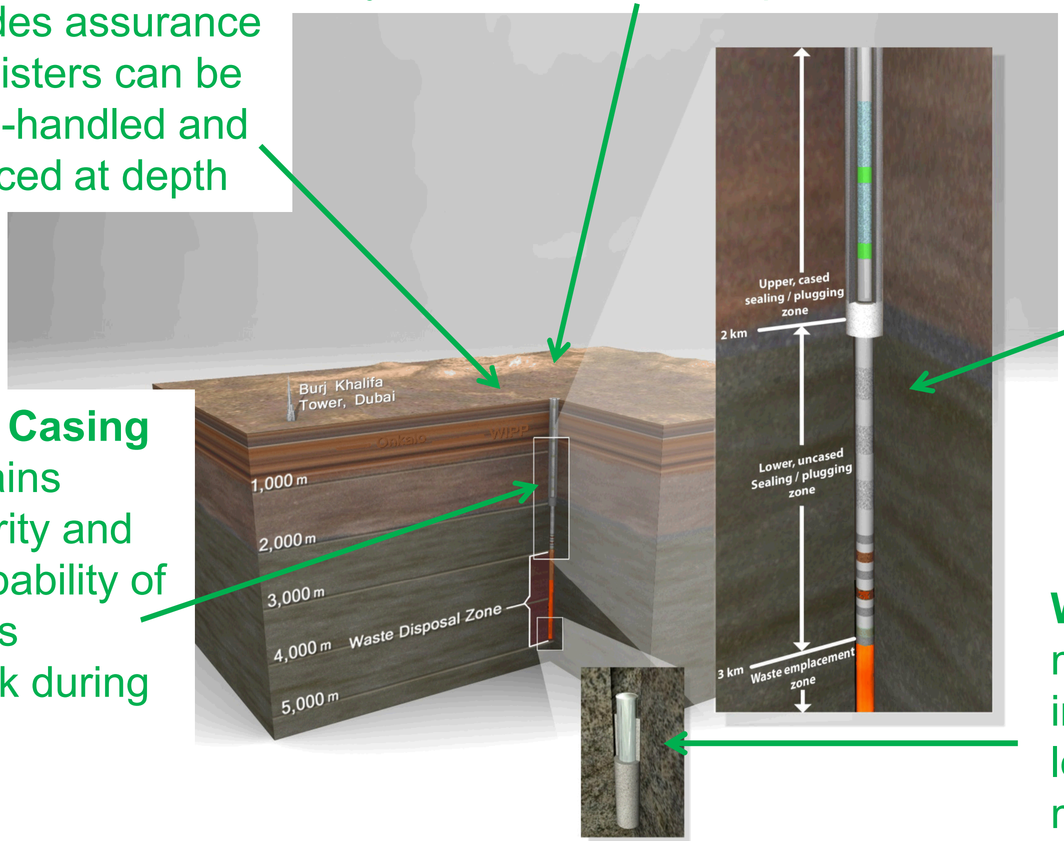
# Deep Borehole Disposal Concept – Safety and Viability Considerations

## Operational Safety and Feasibility (engineering considerations)

**Drilling Technology** exists to drill and case a large-diameter boreholes to 5,000 m depth in crystalline rock at acceptable cost

**Emplacement System Design** provides assurance the waste canisters can be safely surface-handled and can be emplaced at depth

**Borehole Seals** maintain a low-permeability barrier, at least over the time scale of thermally-induced upward flow




**Borehole and Casing Design** maintains borehole integrity and minimizes probability of waste canisters becoming stuck during emplacement

**Waste Canister Design** maintains structural integrity and prevents leakage of radioactive materials during operations

# Deep Borehole Disposal Concept – Safety and Viability Demonstration

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- **Deep Borehole Field Test (DBFT) Objectives**
  - DOE research, development, and demonstration (RD&D) to assess the viability of the concept, without actual radioactive waste
    - Site selection
    - Site characterization and downhole testing/confirmation
    - Design of boreholes, surrogate canisters, and emplacement system
    - Demonstration of deep drilling and construction technology
    - Demonstration of canister handling and emplacement in deep borehole
- **DBFT Timeline**
  - 2014: Siting RFI Issued
  - 2015: Draft Siting RFP Issued
  - 2015: Siting RFP and Siting Decision Planned
  - 2016: Drilling and Downhole Testing in 8.5 in. Characterization Borehole
  - 2017-18: Drilling and Canister Emplacement Demonstration in 17. in Field Test Borehole
  - 2019: Test Analysis and Evaluation of Concept

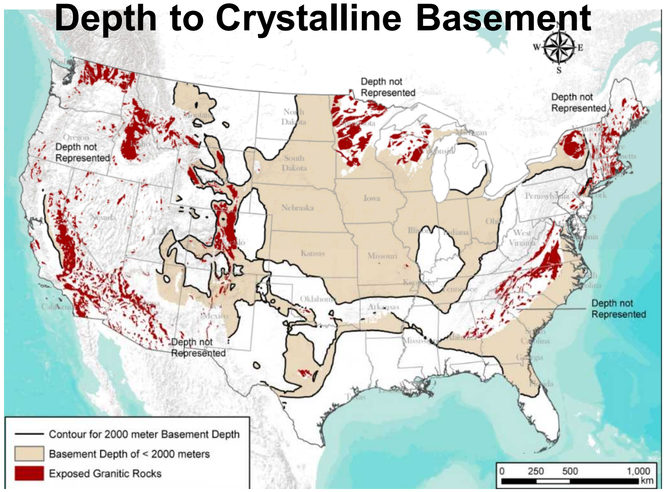
# Siting Considerations for Deep Borehole Disposal

- **Technical and Logistical**
  - Favorable geologic, hydrogeochemical, and geophysical conditions
  - Likelihood of successfully drilling and completing a deep large-diameter borehole
  - Ability to build and maintain the necessary site infrastructure
  - Likelihood of successful surface handling, canister emplacement, and sealing/closure operations
  - Ability to demonstrating pre-closure and post-closure safety
- **Sociopolitical**
  - Recent international experiences indicate that a consent-based process, developed through engagement with stakeholders and/or volunteerism, increases the probability of successful siting

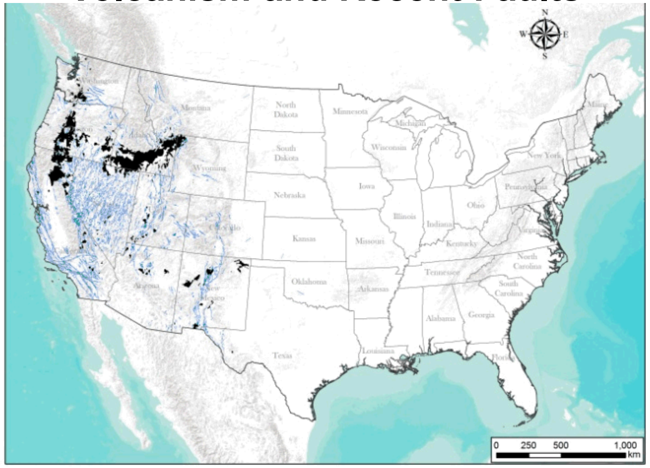
# Siting Considerations – Technical Factors

- **Depth to crystalline basement**
  - Depth less than 2,000 m allows for adequate disposal and seal zones within the crystalline basement
- **Crystalline basement geology**
  - Avoid known or suspected structural complexity (e.g., major faults, shear zones, rift basins)
  - Large plutons of felsic intrusive rocks are generally less heterogeneous and are more desirable
- **Horizontal stress**
  - Large differential in horizontal stress at depth can be an indicator of potential difficulties in drilling a vertical hole and of borehole instability (e.g., borehole breakouts and/or an enhanced disturbed rock zone around the borehole)
- **Seismicity and volcanism**
  - Seismic ground motion risk during operations
  - Quaternary-age faulting and volcanism are indicators for structural complexity and potential future tectonic activity or volcanism

**Depth to Crystalline Basement**



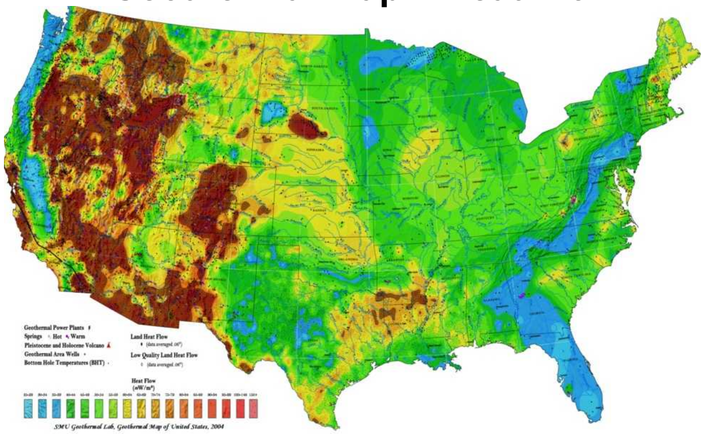

**Volcanism and Recent Faults**



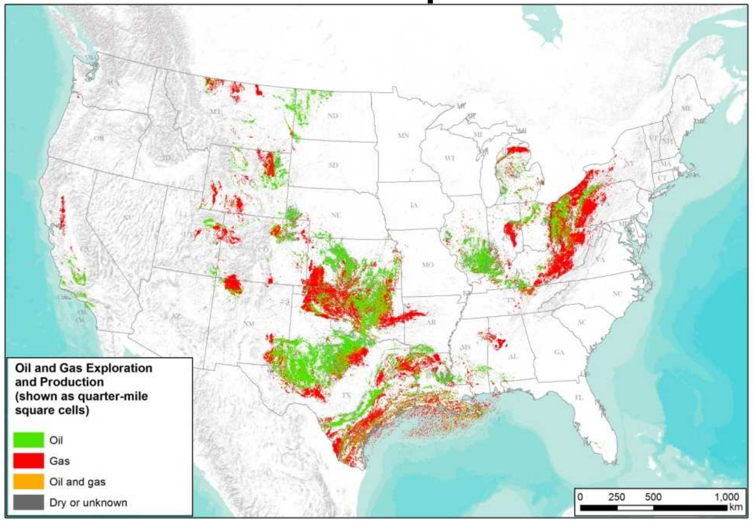
# Siting Considerations – Technical Factors (cont.)

- **Topographic relief and hydraulic gradient**
  - Hydraulic gradients in the deep subsurface are generally related to regional variations in topography and can lead to the potential for upward flow in regional discharge areas. However, deep groundwater can be isolated and stagnant in some hydrogeologic settings, in spite of topographic effects.
- **Geochemical environment**
  - High salinity and geochemically-reducing conditions tend to reduce radionuclide mobility
- **Geothermal gradient**
  - High heat flux can lead to upward hydraulic gradients and is also related to the potential for geothermal drilling
- **Natural resources potential**
  - Petroleum and mineral resources exploration and/or production could lead to human intrusion into the deep borehole and/or impact the release of radionuclides to the overlying sediments.

**Geothermal Map – Heat Flow**



**Oil and Gas Exploration**



# Siting Considerations – Logistical Factors

- **Availability of drilling contractors and support services**
  - Capability for drilling a large-diameter hole to approximately 5,000 m depth
- **Regulations and permitting**
  - Legal and regulatory requirements should be achievable (the regulatory environment is different in different states and for Federal versus private land)
  - Existing regulations for post-closure safety in mined geologic repositories (e.g., 10 CFR 60 and 40 CFR 191) would need to be updated to be applicable to deep borehole disposal
- **Site area**
  - Should be sufficient for drilling, construction, surface facilities (e.g., waste handling), and downhole operations
- **Site access**
  - Reasonable access to roadways and/or railways for transportation of waste and other materials (waste transportation costs could vary considerably depending on the disposal site location relative to waste storage or nuclear power plant locations)

# Siting Considerations – Sociopolitical Factors

- Proximity to population centers
- Opinion (e.g., support or opposition) of state and local entities and other stakeholders towards nuclear facilities

# Summary and Conclusions

- **Safety and viability of deep borehole disposal relies on:**
  - Great depth of disposal
  - Isolation provided by the deep natural hydrogeochemical environment
  - Integrity of the borehole seals
- **Siting considerations include:**
  - Technical, logistical, and sociopolitical factors
- **Recently initiated DBFT designed to assess the viability of the concept**
  - Deep borehole drilling and construction technology
  - Verification of deep hydrogeochemical conditions
  - Evaluation of canister designs and materials
  - Development of engineering methods for downhole canister emplacement and seals deployment