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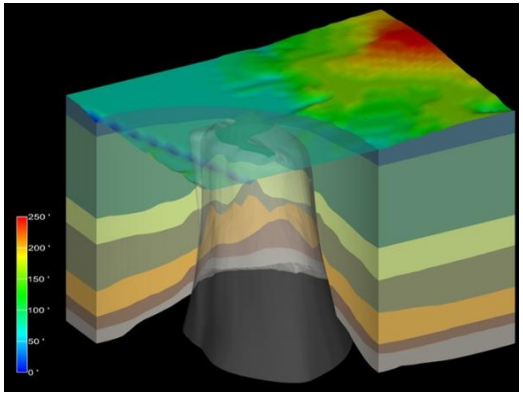

Hydrogeology of Deep Borehole Disposal for High-Level Radioactive Waste

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U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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Outline

- Deep borehole disposal concept
- Disposal concept viability and safety
- Deep hydrogeology and disposal safety
- Hydrogeological characterization challenges
- Conclusions

Deep Borehole Disposal Concept

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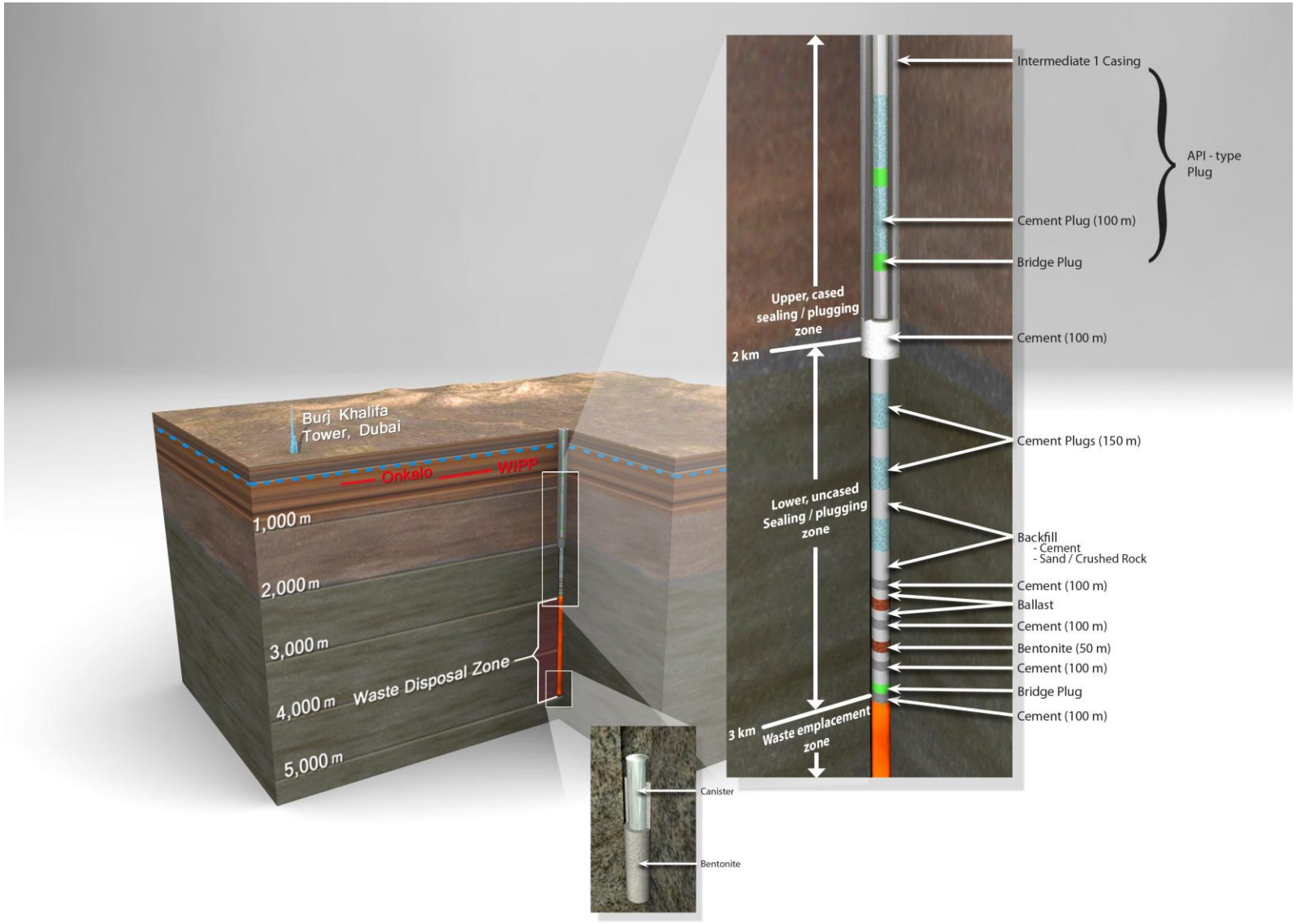
- Disposal concept consists of drilling a borehole or array of boreholes into crystalline basement rock to about 5,000 m depth
- Borehole casing or liner assures unrestricted emplacement of waste canisters
- Waste would consist of spent nuclear fuel and/or high-level radioactive waste
- Approximately 400 waste canisters would be emplaced in the lower 2,000 m of the borehole
- Upper borehole would be sealed with compacted bentonite clay , cement plugs, and cemented backfill

Deep Borehole Disposal Concept



Deep Borehole Disposal Concept: Viability and Safety

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- Crystalline basement rocks within 2,000 m of the surface are common in many stable continental regions
- Existing drilling technology permits reliable construction at acceptable cost
- Low permeability and long residence time of high-salinity groundwater in deep continental crystalline basement at many locations suggests very limited interaction with shallow fresh groundwater resources
- Geochemically reducing conditions at depth limit the solubility and enhance the sorption of many radionuclides in the waste
- Density stratification of saline groundwater underlying fresh groundwater would oppose thermally induced groundwater convection

Disposal Concept Viability: Depth to Crystalline Basement

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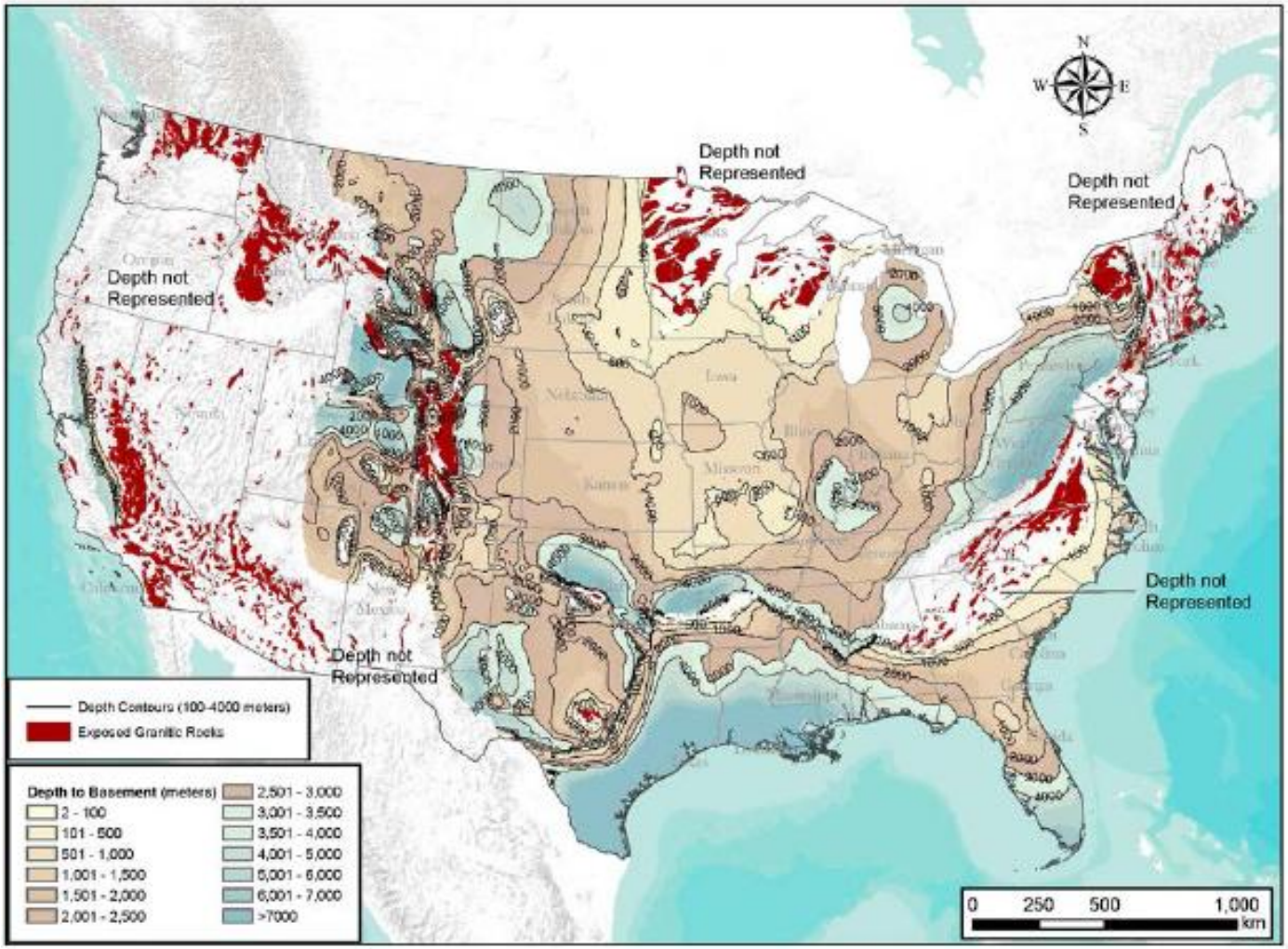

from Perry (2014)

Key Elements of the Disposal Safety Case Related to Hydrogeology

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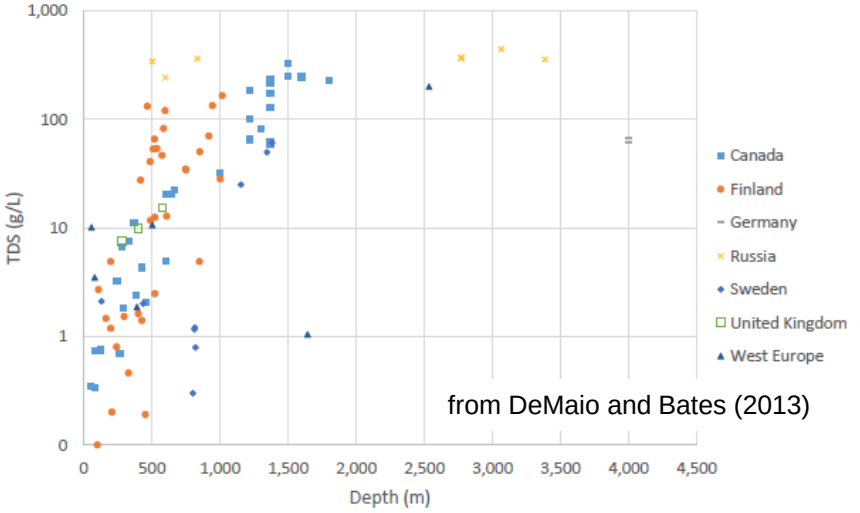
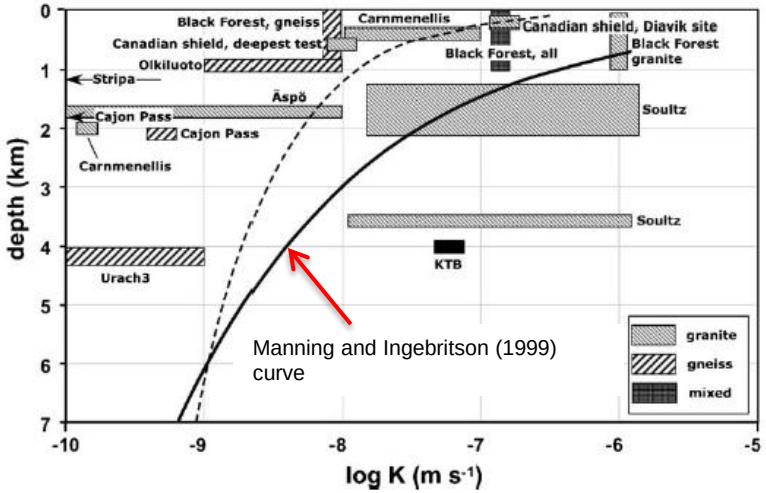
- Deep fluids in the crystalline basement have very long residence times and have been isolated from shallow groundwater on geologic time scales
- Deep groundwater is highly saline and geochemically reducing
- Deep crystalline rocks have low bulk permeability and lack large-scale, high-permeability structural features that extend to the surface or shallow subsurface
- The deep hydrogeological system does not have ambient upward hydraulic gradients in fluid potential
- Borehole seals maintain their physical integrity as permeability barriers, at least over the time scale of thermally-induced groundwater flow

Hydrogeological Characterization Priorities

- Groundwater age and history (e.g. Holland et al., 2013)
- Groundwater salinity and geochemistry
- Potentially overpressured conditions
- Permeability in the host rock and disturbed rock zone near the borehole
- Chemical and mineralogical interactions with borehole seals

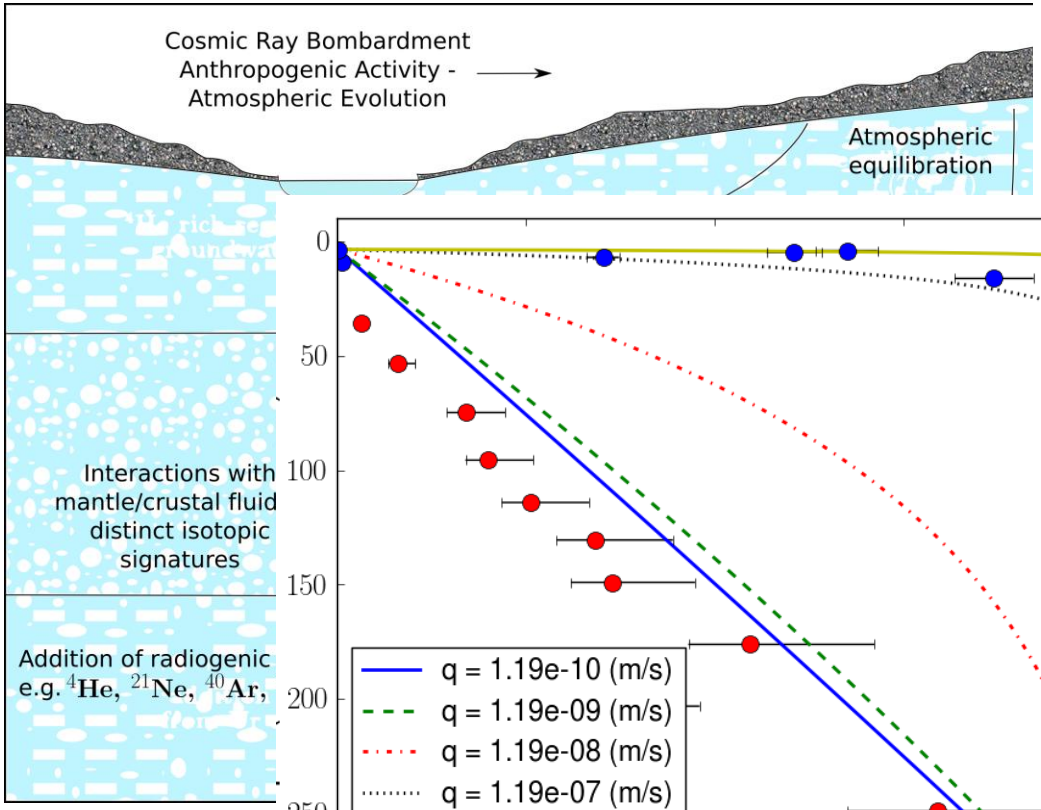


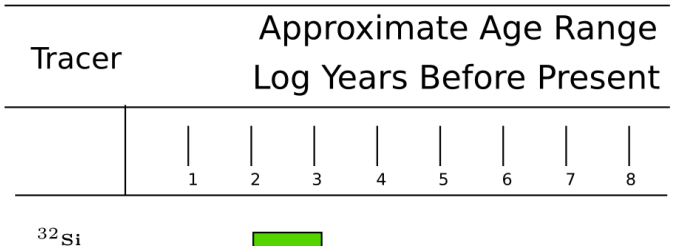
from DeMaio and Bates (2013)

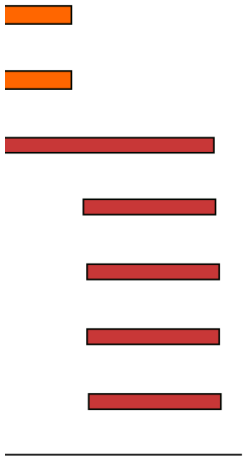


from Stober and Bucher (2007)

Fluid Age and History: Environmental Tracers

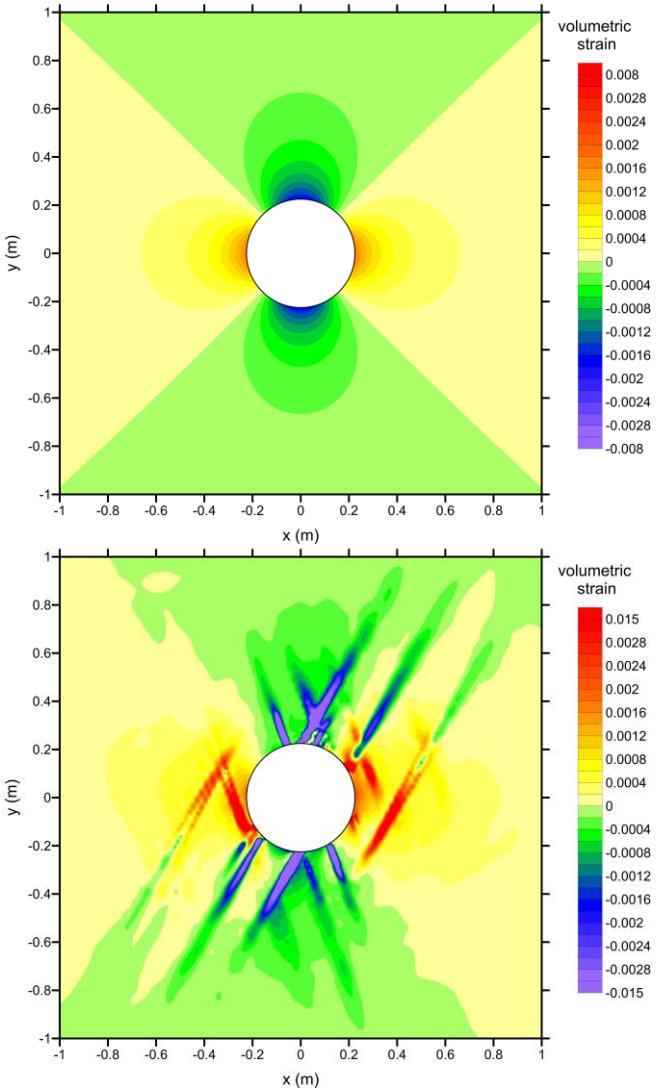






Hydrogeological Characterization: Disturbed Rock Zone

- Disturbed rock zone near the borehole wall may have enhanced permeability relative to the host rock
- Preliminary modeling of mechanical response under anisotropic horizontal stress suggests potential preferential permeability increase in some fractures
- Vertical dipole pumping and tracer tests can be used to evaluate the flow and transport characteristics of the disturbed rock zone



Characterization Challenges

- Identifying and sampling representative fluids in fractured, low-permeability crystalline rocks
- Accurately determining fluid potential as a function of depth to assess potentially overpressured conditions
- Characterizing the disturbed rock zone near the borehole
- Determining the long-term interactions between groundwater and borehole seals, and assessing the impacts on seals integrity
- Conducting logging and testing in large-diameter boreholes (17-inch diameter in reference design)

Conclusions

- **Multiple factors indicate the feasibility and safety of the deep borehole disposal concept**
- **Field test site selection guidelines indicate that large areas with favorable geological characteristics exist in the conterminous U.S.**
- **Groundwater characterization should focus on aspects of the system critical to demonstrating safety of the deep borehole disposal system:**
  - **Groundwater age and history**
  - **Salinity and geochemistry**
  - **Potential for vertical fluid movement**
  - **Permeability in the host rock and disturbed rock zone**
  - **Borehole seals integrity and durability**