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Geologic Disposal Options in the USA

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Frank Hansen, PhD, PE
Sandia National Laboratories
Albuquerque New Mexico
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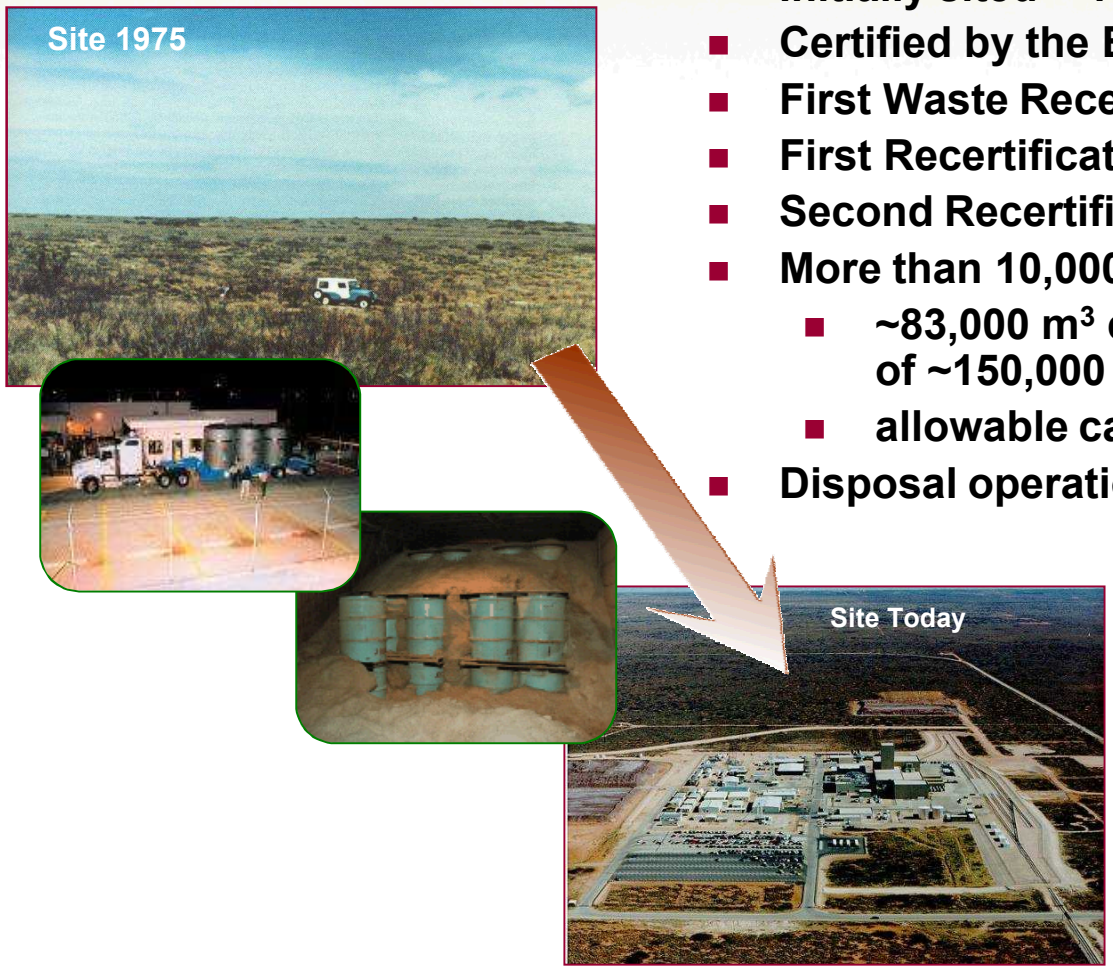
Saga of Geologic Repositories

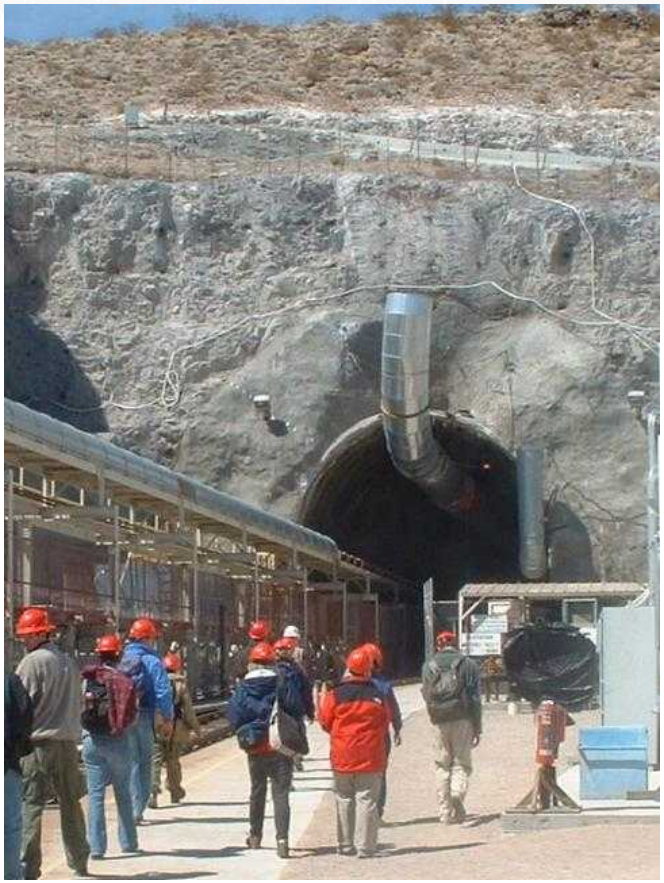
- "Yucca Mountain is not a workable option" (DOE licensing motion, March 3, 2010); however the Nuclear Waste Policy Act remains in effect and Yucca Mountain remains the only legally available option
- The Waste Isolation Pilot Plant (WIPP) is in operation for transuranic waste, managed by the DOE Office of Environmental Management
- Blue Ribbon Commission on America's Nuclear Future recommendations
- Back to the place of beginning again

Waste Isolation Pilot Plant
Geologic Disposal of Transuranic Waste



- Initially sited – 1975
- Certified by the EPA – 1998
- First Waste Receipt – March 26, 1999
- First Recertification – March 2006
- Second Recertification – November 2010
- More than 10,000 shipments to date
  - ~83,000 m^3 emplaced, projected inventory of ~150,000 m^3
  - allowable capacity of ~175,000 m^3
- Disposal operations continue: 2012 → 2033?

Yucca Mountain Exploratory Studies Facility



Introduction

- The USA has many geologic settings suitable for deep geologic disposal of nuclear waste
- There is substantial confidence that compliance with regulatory standards can be demonstrated
- Rock types include salt, shale, and granite (and other massive, competent rock types)
- Media-specific, internationally recognized disposal concepts

Siting and Geologic Considerations

- **Depth – The disposal horizon is determined by site-specific conditions**
- **Unit Thickness – Maximal thickness is desired to ensure radionuclide migration does not exceed regulatory criteria or boundaries**
- **Uniformity and Structure – The potential repository interval and surrounding rock should be reasonably homogeneous both vertically and horizontally**
- **Seismicity –Seismically quiescent regions favor repository design, operations, and long term performance**

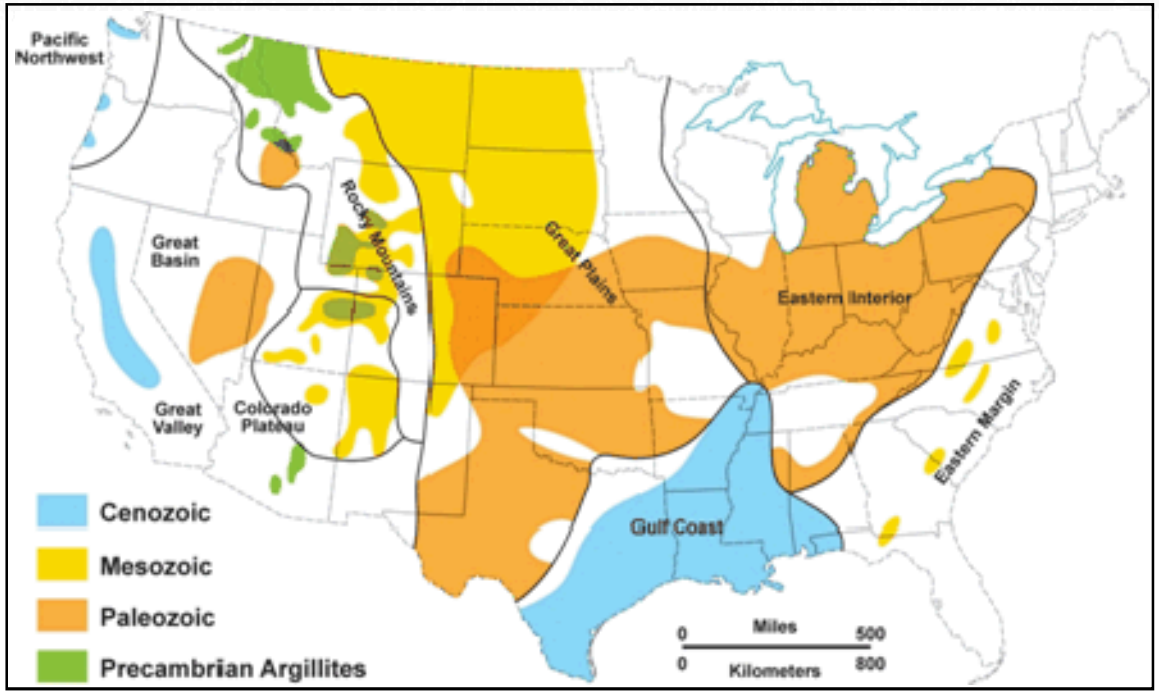
Desirable Attributes of the Geologic Setting

- **Hydrogeology – Low hydraulic conductivity**
  - Approximately 10^{-12} m/sec or less
- **Self-sealing –Plastic Deformation Characteristics**
  - Reestablish diffusion-dominated transport conditions
- **Hydrogeochemistry – Reducing Chemical Conditions**
  - Limit corrosion of engineered barriers and waste forms
  - Reduce solubility for most radionuclides
  - Improve sorption

Granite Outcrops in the United States

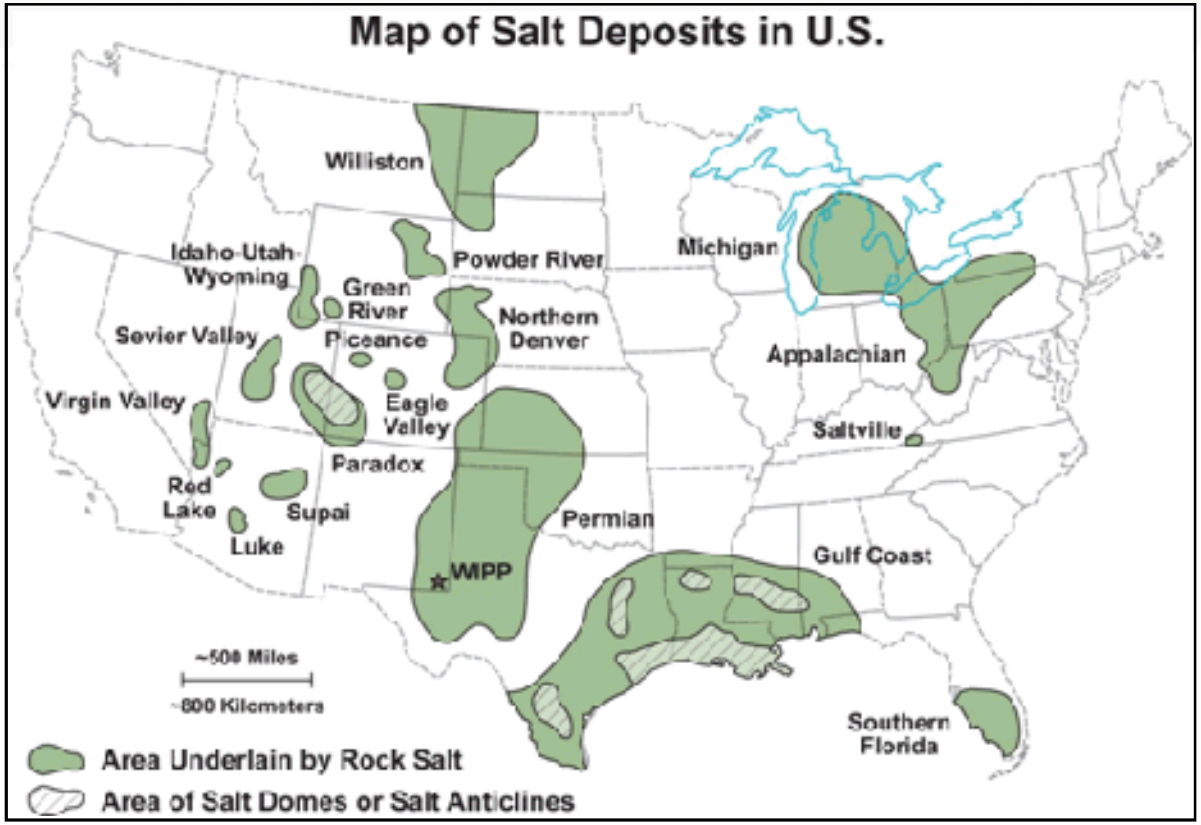
- Includes a range of competent, crystalline rock types
- The USA had an R&D and siting program for crystalline rock, until the 1980s
- Fractured/unfractured
- Saturated/unsaturated
- International progress (Sweden and Finland)

Shale Provinces in the United States



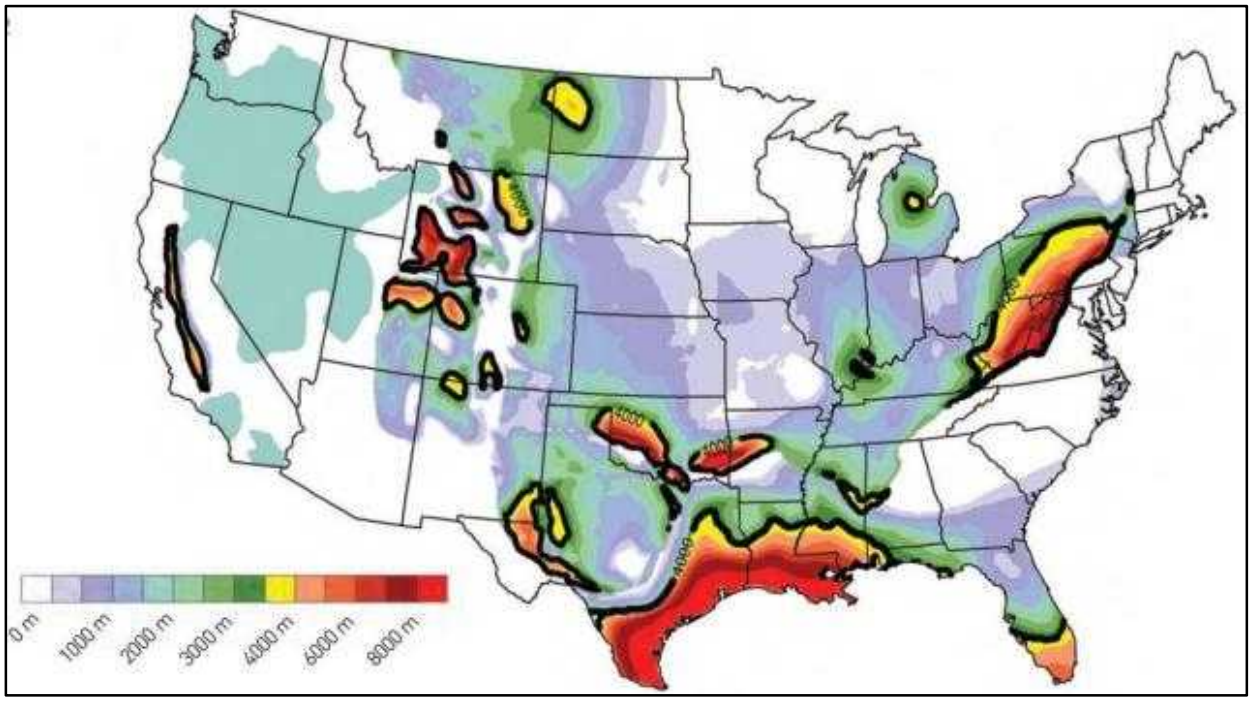
- Includes a range of plastic to indurated clay-rich lithologies
- The USA had active shale repository programs in the 1970s and 1980s
  - Thermomechanical laboratory and field tests
- International progress (France and Switzerland)

Salt Deposits in the United States



- The USA has supported significant salt repository investigations
  - Project Salt Vault
  - Avery Island
  - WIPP
- International interest is high (Germany)

Depth to Basement Rock in the United States



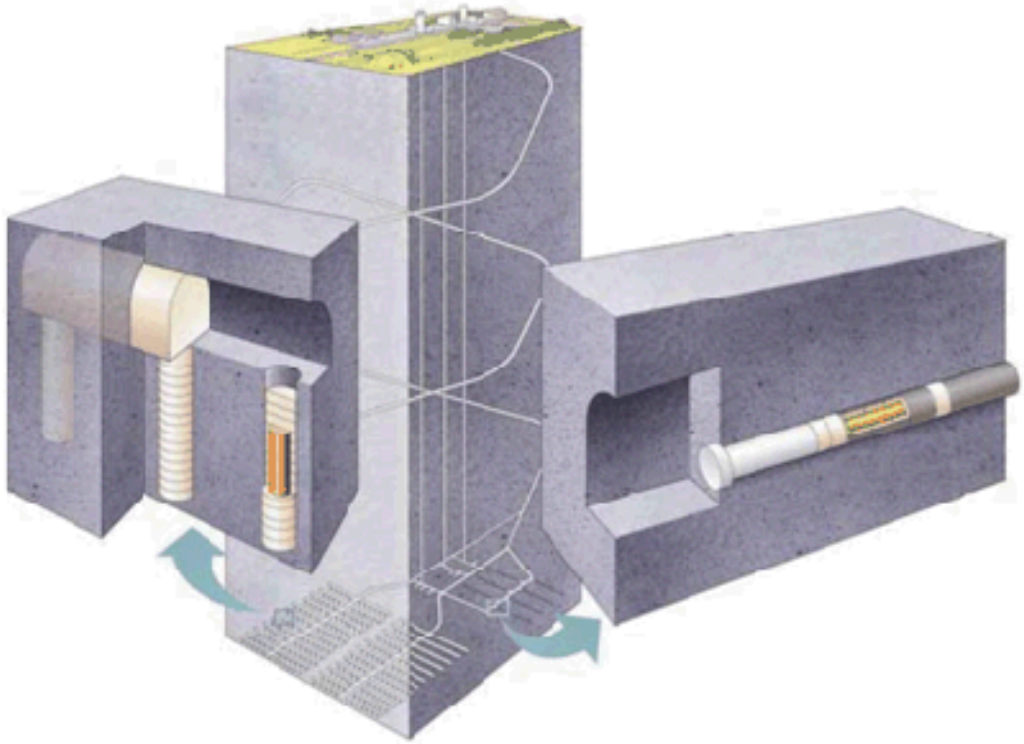
- Very deep holes (3 to 5 km)
- Crystalline basement rock
- Less research than mined repositories

Repository Disposal Concepts

- **A repository disposal concept requires**
  - Waste Stream + Geologic Setting + Concept of Operations
- **Concepts for geologic disposal have been developed in several countries**
- **The following slides give a general overview**
  - Granite/crystalline rock
  - Clay/shale
  - Salt repository
  - Deep borehole disposal concept

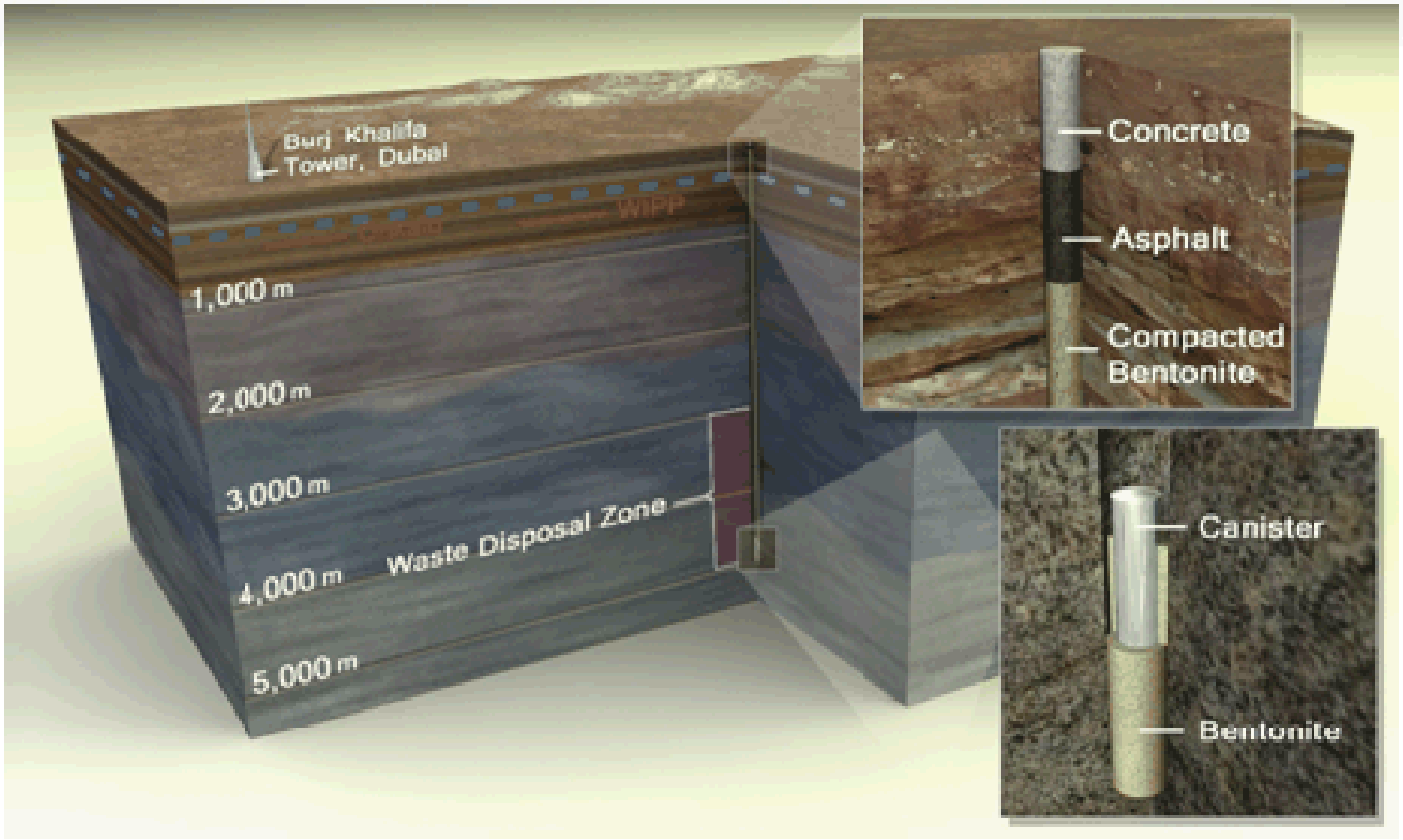
Representative Disposal Concept for Mined Granite Repository

- Sweden, Finland, Spain, Switzerland, China
- Spent fuel or HLW
- Reducing conditions
- Vertical & horizontal emplacement modes
- Well studied concept



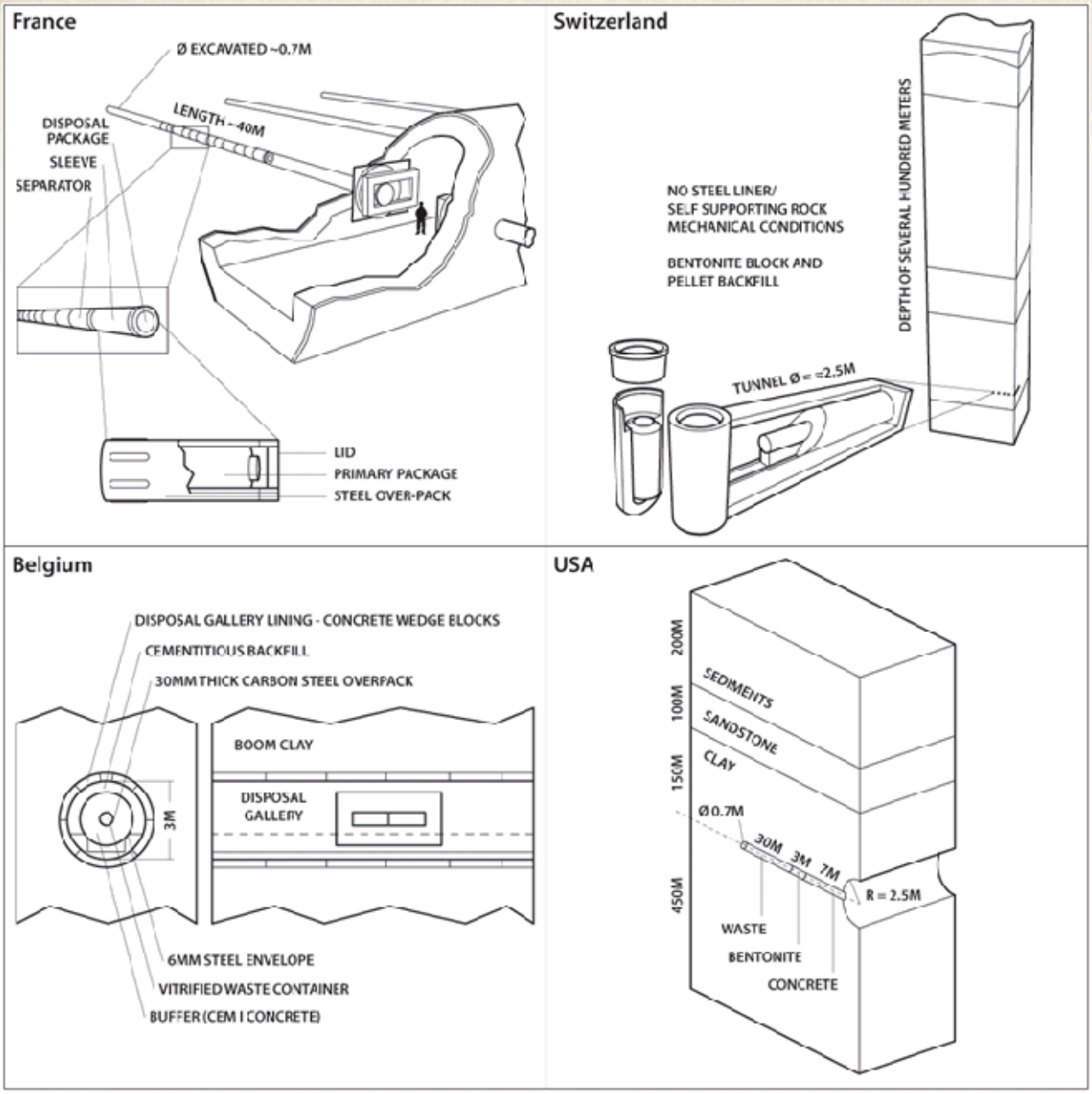
Waste Handling/Storage Demonstration in Granite at the Nevada Test Site

Deep Borehole Disposal Concept



Clay/Shale Disposal Concepts

- Borehole & in-drift emplacement modes
- Reducing environment
- Steel canister
- Plugs and seals



Disposal Configuration for Transuranic Waste at the WIPP

Simulating HLW at WIPP

Relative Attributes of Disposal Options

Property	Salt	Shale	Granite	Deep boreholes
Thermal conductivity	High	Low	Medium	Medium
Permeability	Practically impermeable	Very low to low	Very low (unfractured) to permeable (fractured)	Very low
Strength	Medium	Low to medium	High	High
Deformation behavior	Visco-plastic (creep)	Plastic to brittle	Brittle	Brittle
Stability of cavities	Self-supporting on decade scale	Artificial reinforcement required	High (unfractured) to low (highly fractured)	Medium at great depth
In situ stress	Isotropic	Anisotropic	Anisotropic	Anisotropic
Dissolution behavior	High	Very low	Very low	Very low
Sorption behavior	Very low	Very high	Medium to high	Medium to high
Chemical	Reducing	Reducing	Reducing	Reducing
Heat resistance	High	Low	High	High
Mining experience	High	Low	High	Low
Available geology*	Wide	Wide	Medium	Wide
Geologic stability	High	High	High	High
Engineered barriers	Minimal	Minimal	Needed	Minimal

Favorable property Average Unfavorable property

*** See figures in text.**

Concluding Remarks

- The US has multiple, technically promising geologic disposal options
- Site screening and suitability evaluations depend on the disposal concept
- New radioactive waste management policy will determine how and when siting and suitability evaluations are performed
- Evaluations of a particular disposal concept will require a legal/regulatory framework
- Nuclear Waste Administration Act of 2013 Discussion Draft