Maintaining Chemically Reducing Waste-Package Conditions

Dr. Charles W. Forsberg

Dr. Leslie R. Dole

Oak Ridge National Laboratory*
P.O. Box 2008; Oak Ridge, TN 37831-6179
Tel: (865) 574-6783; E-mail: forsbergcw@ornl.gov

For
2002 Materials Research Society Meeting
Materials Research Society
Boston, Massachusetts
December 4, 2002

*Managed by UT-Battelle, LLC, for the U.S. Department of Energy under contract DE-AC05-00OR22725. The submitted manuscript has been authored by a contractor of the U.S. Government under contract DE-AC05-00OR22725. Accordingly, the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U.S. Government purposes.

Overview

- The Yucca Mountain repository has an oxidizing geochemical environment
- Degradation rates for spent nuclear fuel (SNF) are slower in reducing environments than in oxidizing environments
- Shielded waste packages (WPs) may contain large quantities of reducing agents [depleted uranium dioxide (DUO_2) and iron (Fe)]
- The potential exists to create local zones of reducing agents around the SNF to improve long-term repository performance

Multipurpose Cask Design

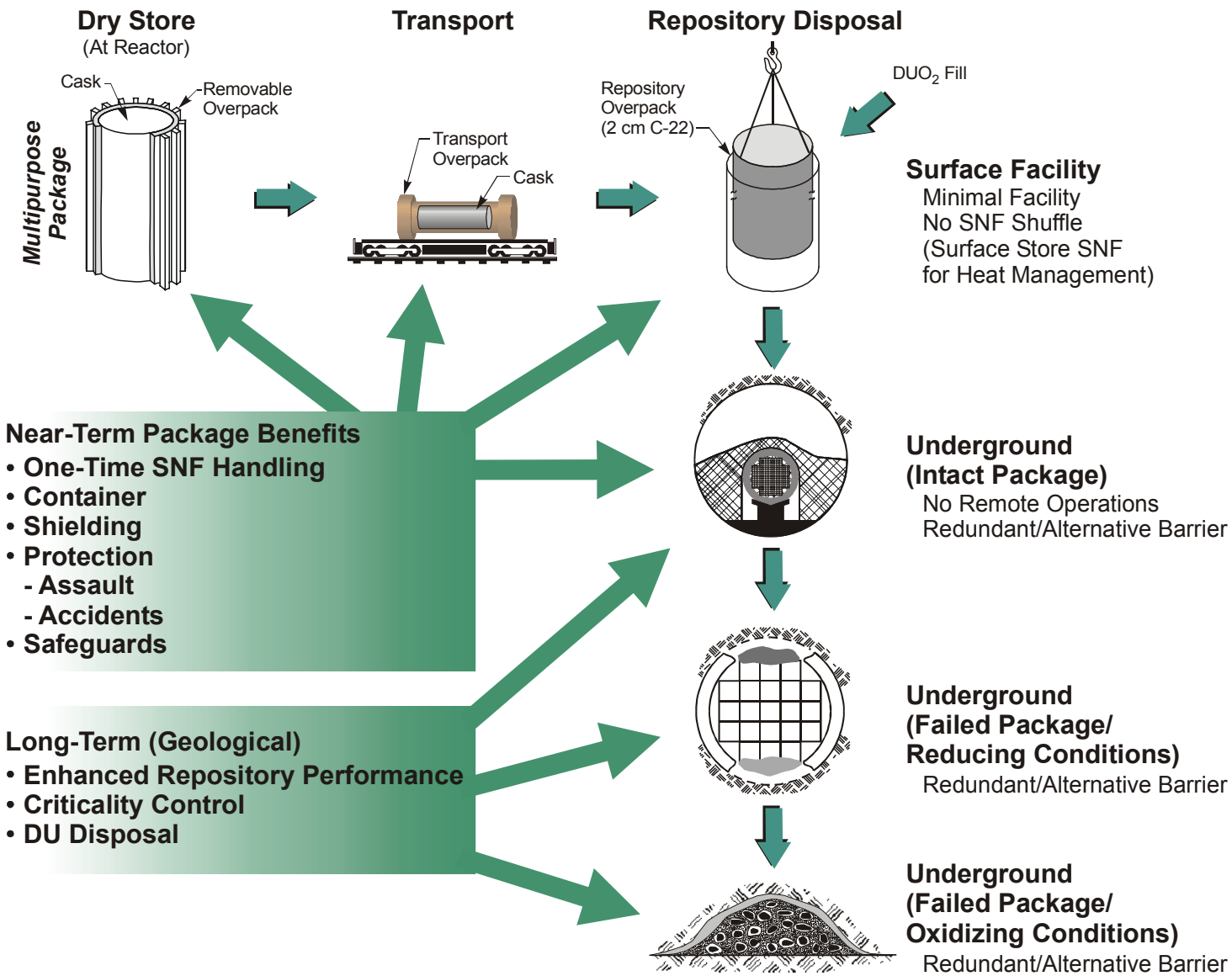
—An Advanced WP System—

SNF loaded into cask at reactor
Cask used for reactor storage

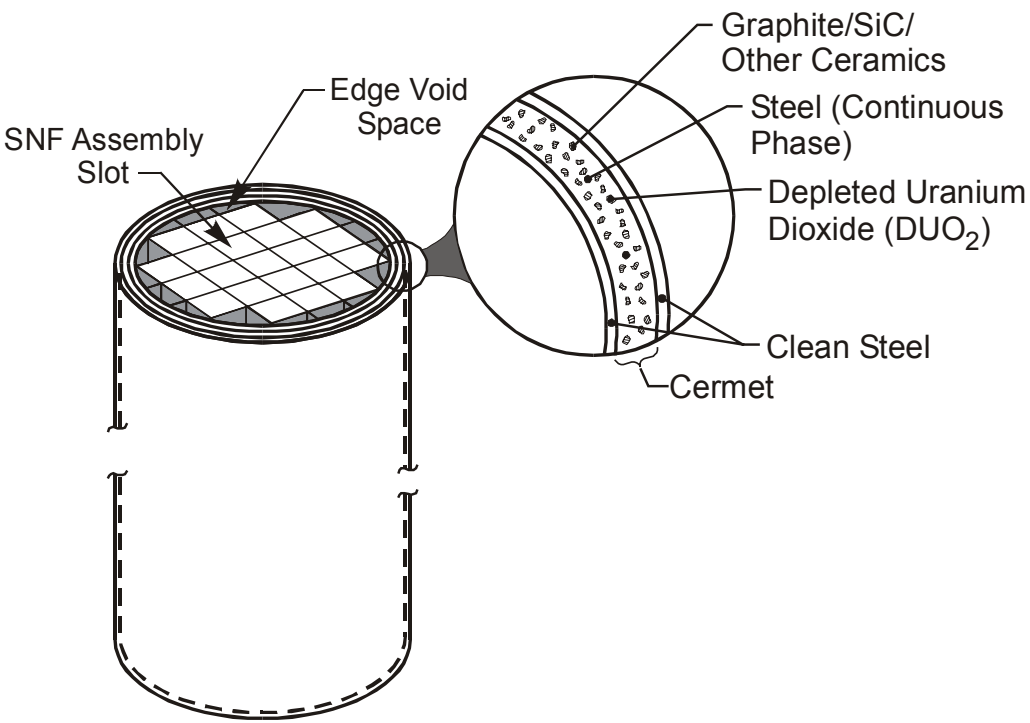
Cask used for transport

Cask used for disposal

Repository System with Multipurpose Cask



Cermets (Ceramics in Metal Matrix) are the Enabling Technology for a High-Performance Multipurpose Cask

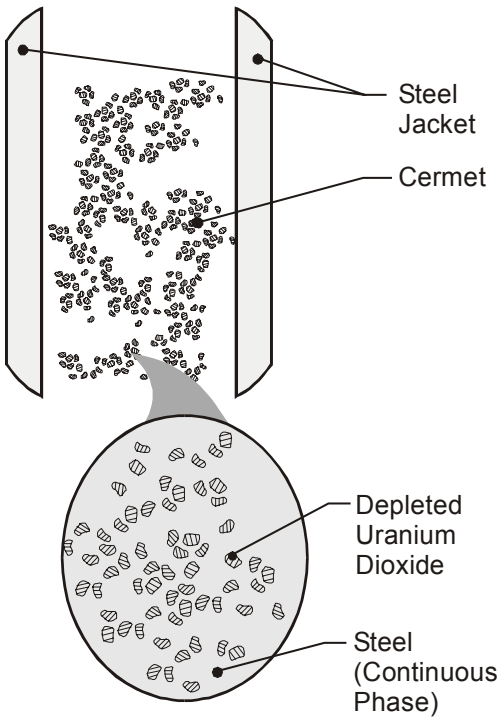


Functions

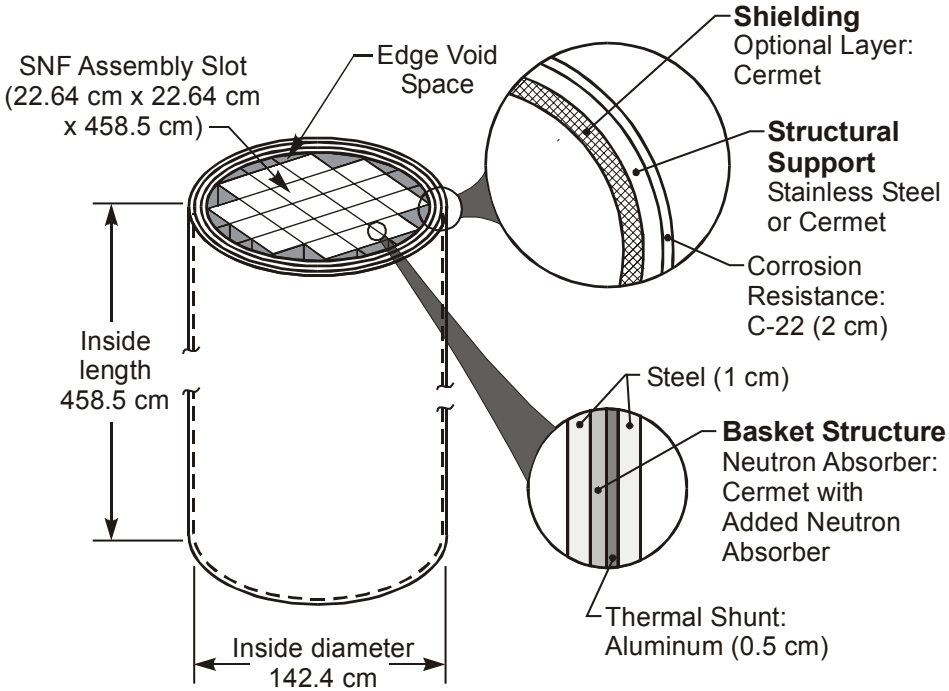
- Radiation Shielding
  - Gamma: High-Density DUO_2/Other
  - Neutron Moderation/Absorption
    - Oxygen in DUO_2
    - Carbon in SiC and Graphite
- Assault Protection: Multilayer Cermet (Traditional Armor)
  - Ceramic (Al_2O_3, DUO_2, SiC, Other)
  - Metal
- Safeguards and Theft
  - Large Mass
  - Vault Construction: Multilayer Cermet
- Decay Heat Removal
  - High-Conductivity Steel Matrix

Such Casks Imply Large Quantities (~100 tons) of Reducing Agents (Fe and DUO_2) Near the SNF

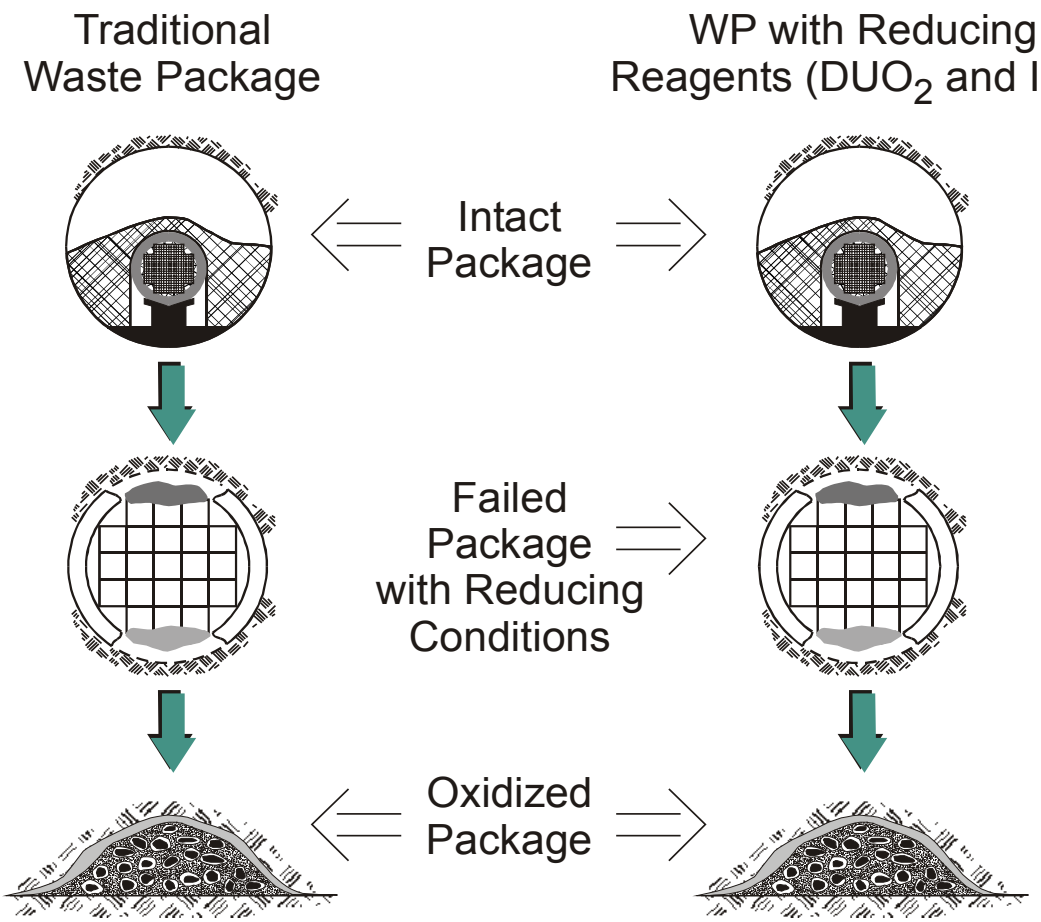
Cermet



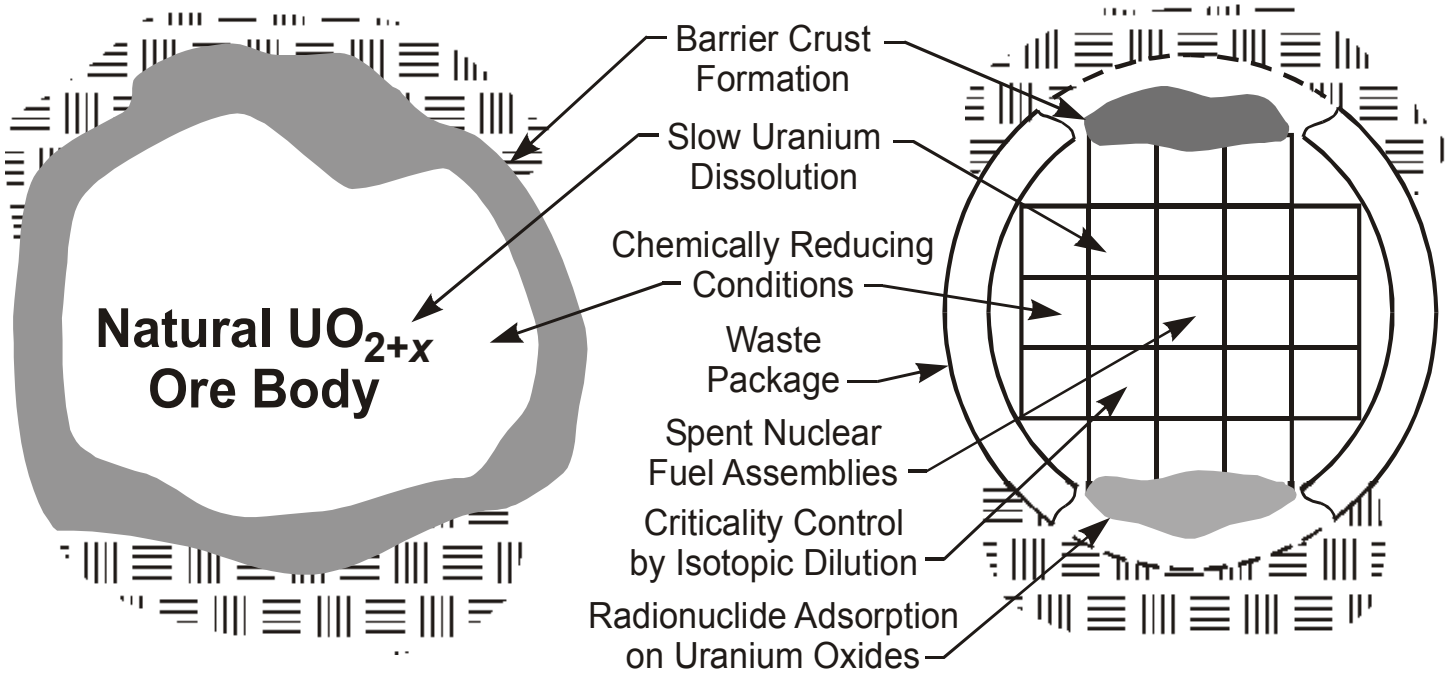
Applications



Large Quantities of Reducing Reagents May Create Long-Term Reducing Conditions Near the SNF

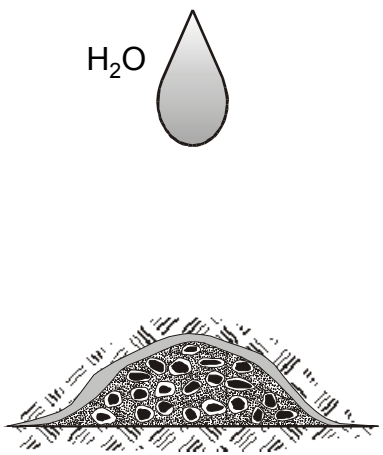


Some Uranium Ore Deposits Have Remained Intact for Millions of Years by Sacrificial Oxidation of Outer Layers

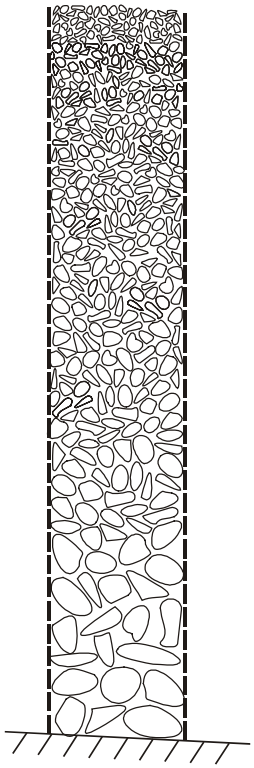


Oxygen Can Reach the SNF by Several Routes

Groundwater with Dissolved Oxygen



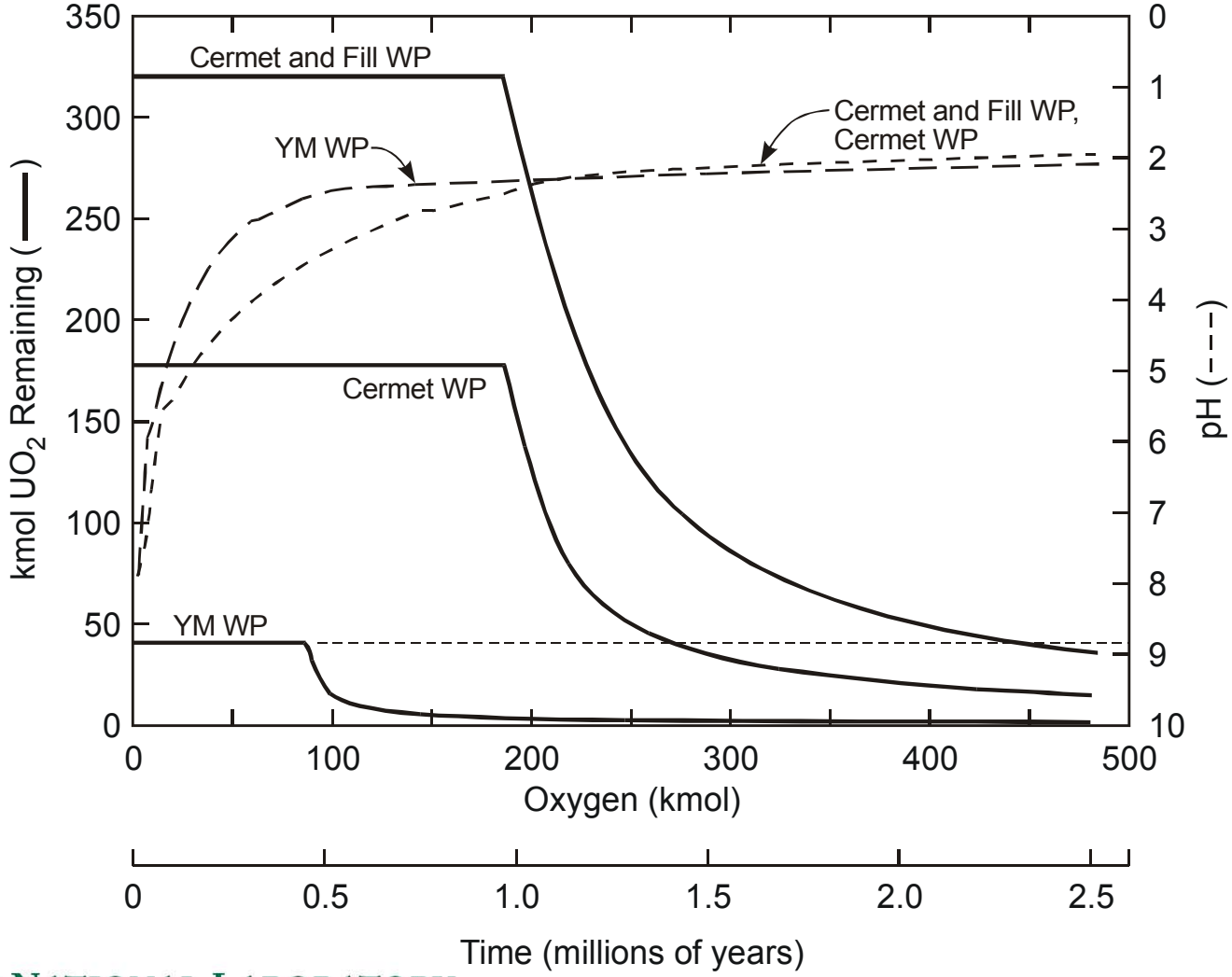
Oxygen in Disposal Drift



- Barometric pumping
- Diffusion of oxygen through gas phase
- Diffusion of oxygen through capillary waste

Oxidation by Oxygen Dissolved in Groundwater

Repository WP and SNF Oxidation by Oxygen in Groundwater is Slow



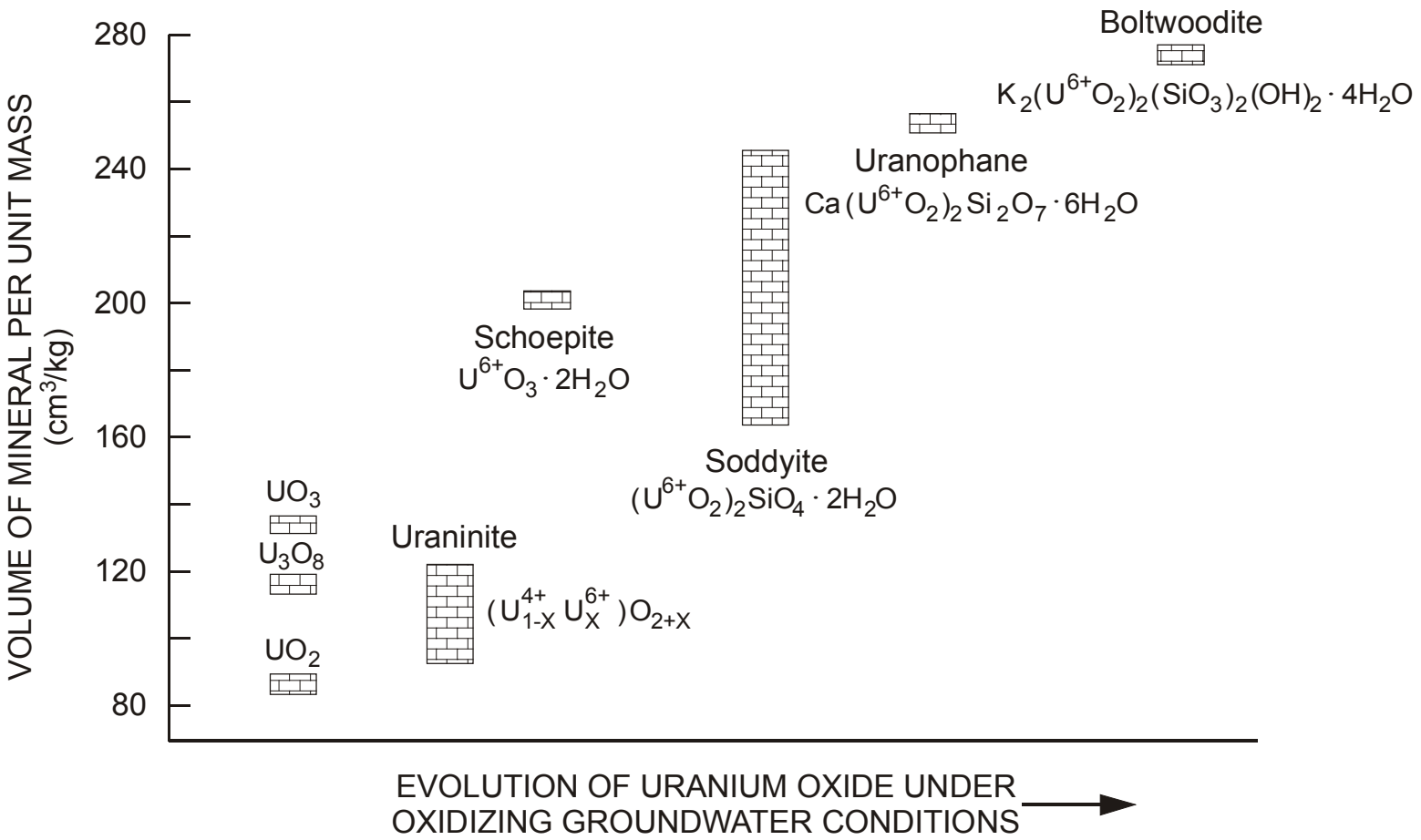
Oxidation by Diffusion of Oxygen from the Repository Drift to the SNF

Barometric Pumping

Diffusion in Air

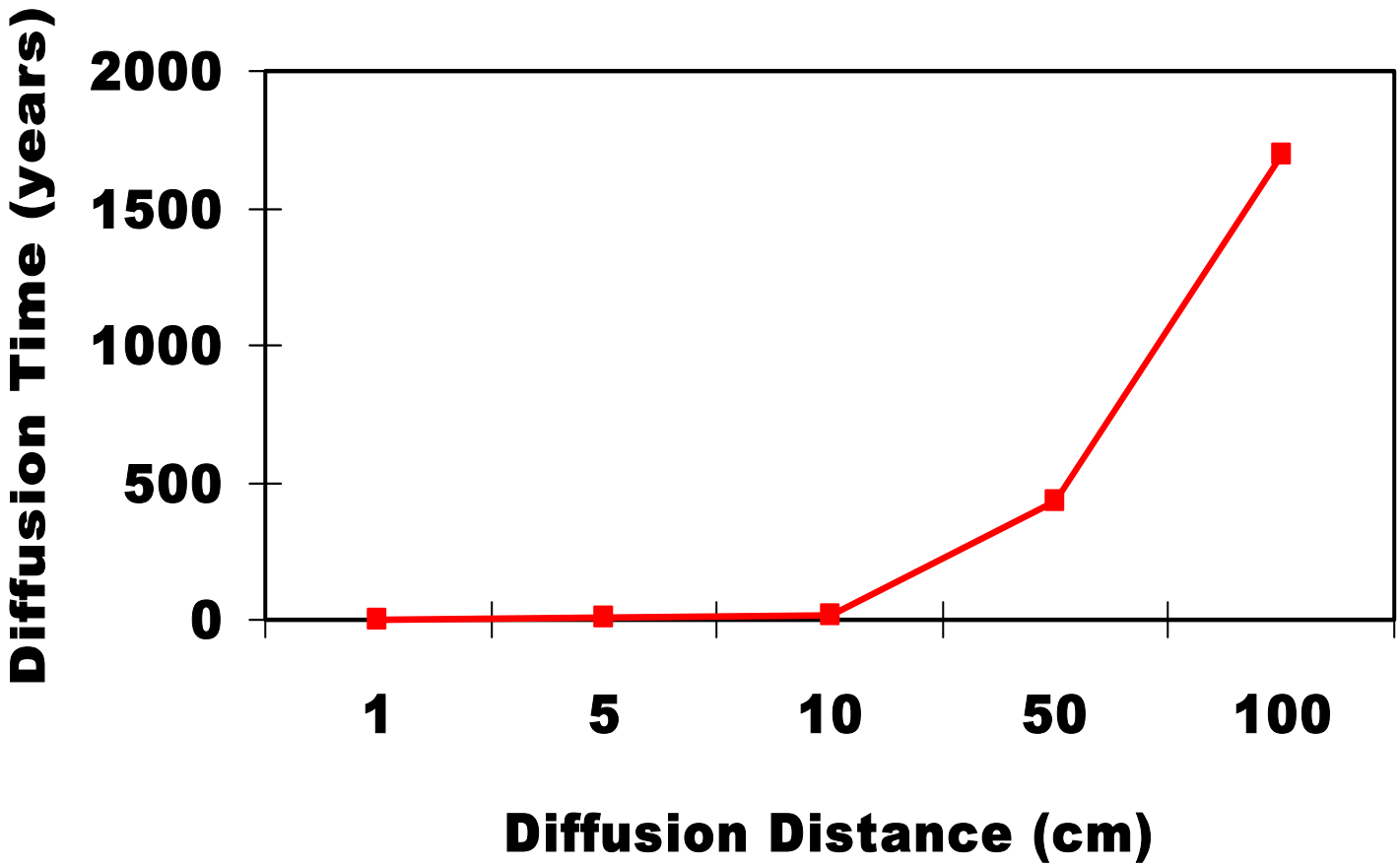
Diffusion in Water

Uranium Oxidation Over Time Tends to Block Flow Channels in a WP



Oxygen Transport by Gas Diffusion is Slow

(time for 1 Mole of O_2 per 100 cm^2 of corroding surface)



Oxygen Transport by Liquid Diffusion is Slower than Air Diffusion

- Diffusion coefficients for oxygen in water are 10,000 times smaller than those for air
- Capillary action is expected to fill void spaces in the degraded waste form with water
  - Oxidation fills void spaces
  - DUO_2 and iron degradation products are hydrated oxides with wetted surfaces

Conclusions

- Shielded WPs add very large quantities of reducing agents next to the SNF
- Different lines of evidence suggest that these reducing agents can significantly slow the degradation of the SNF
- Significant work is required to better quantify this benefit of casks with large quantities of reducing materials