NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Engineered Barriers: What are they and how do they work?

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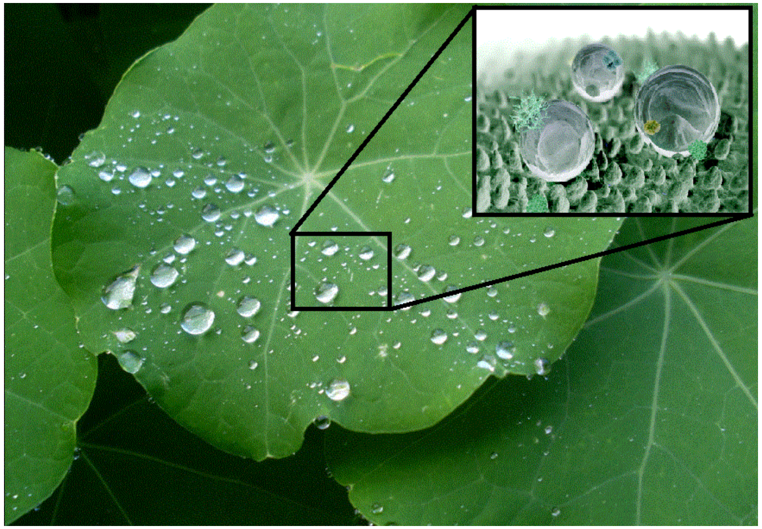
Engineered Barrier Systems

Types of Barriers – Engineered vs. Natural

Natural Barrier



Engineered Barrier

- Natural barriers are products of the natural world while engineered barriers are human developments
- Often times engineered barriers will imitate or work with natural barriers

Properties of Engineered Barriers

Engineered Barriers serve a specific protective function.

- Physical/Structural
- Chemical
- Radiation/Thermal

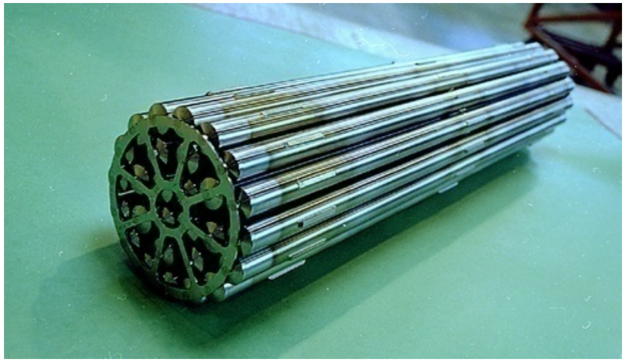
Engineered Barriers are chosen, constructed and placed based on the desired barrier properties.

What are we isolating? CANDU Fuel

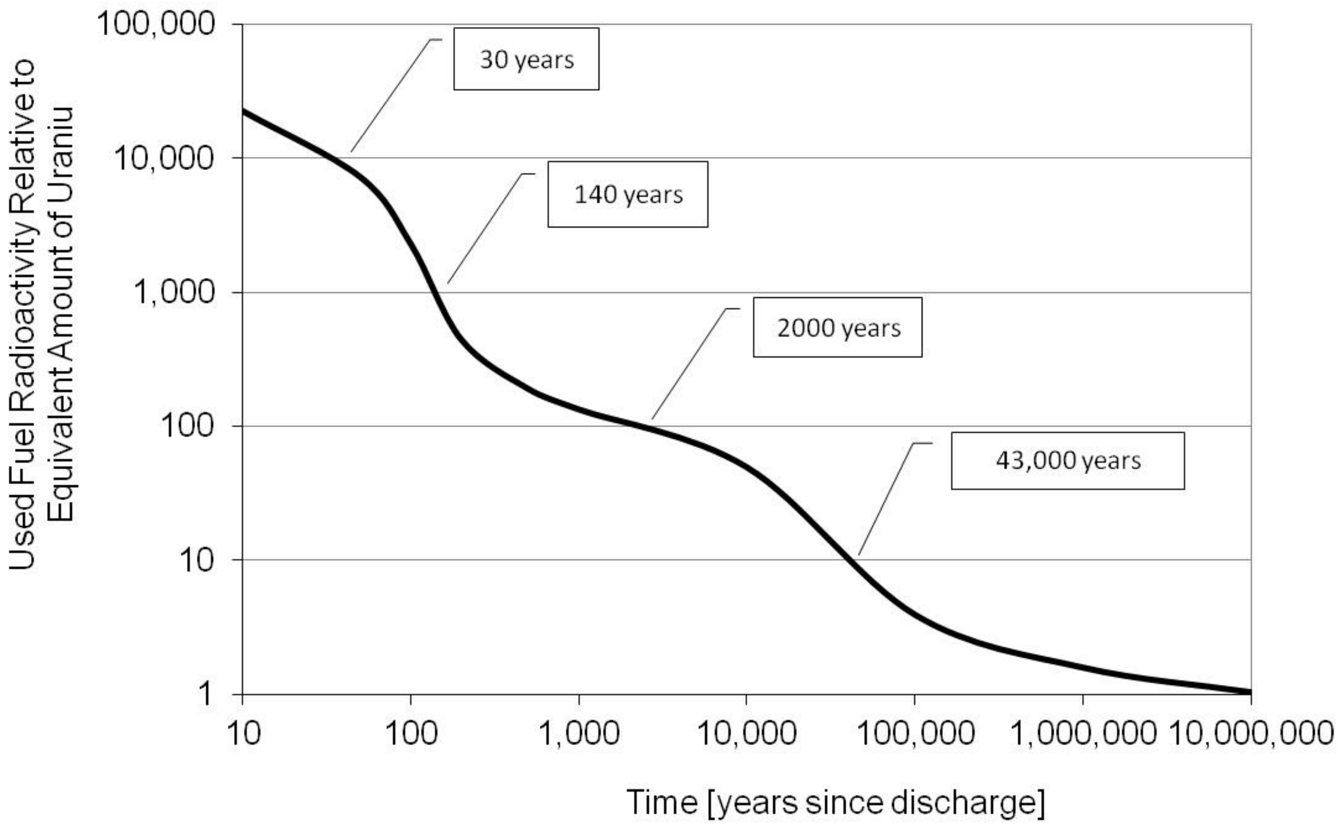
- Natural uranium based (not enriched)
  - No spontaneous nuclear problem (Can’t go “critical”)
  - Ceramic form (less reactive chemically)

- Still hazardous

Spent Fuel Composition	
UO_2	98.5%
Other radioactive	0.5%
Stable atoms	1.0%

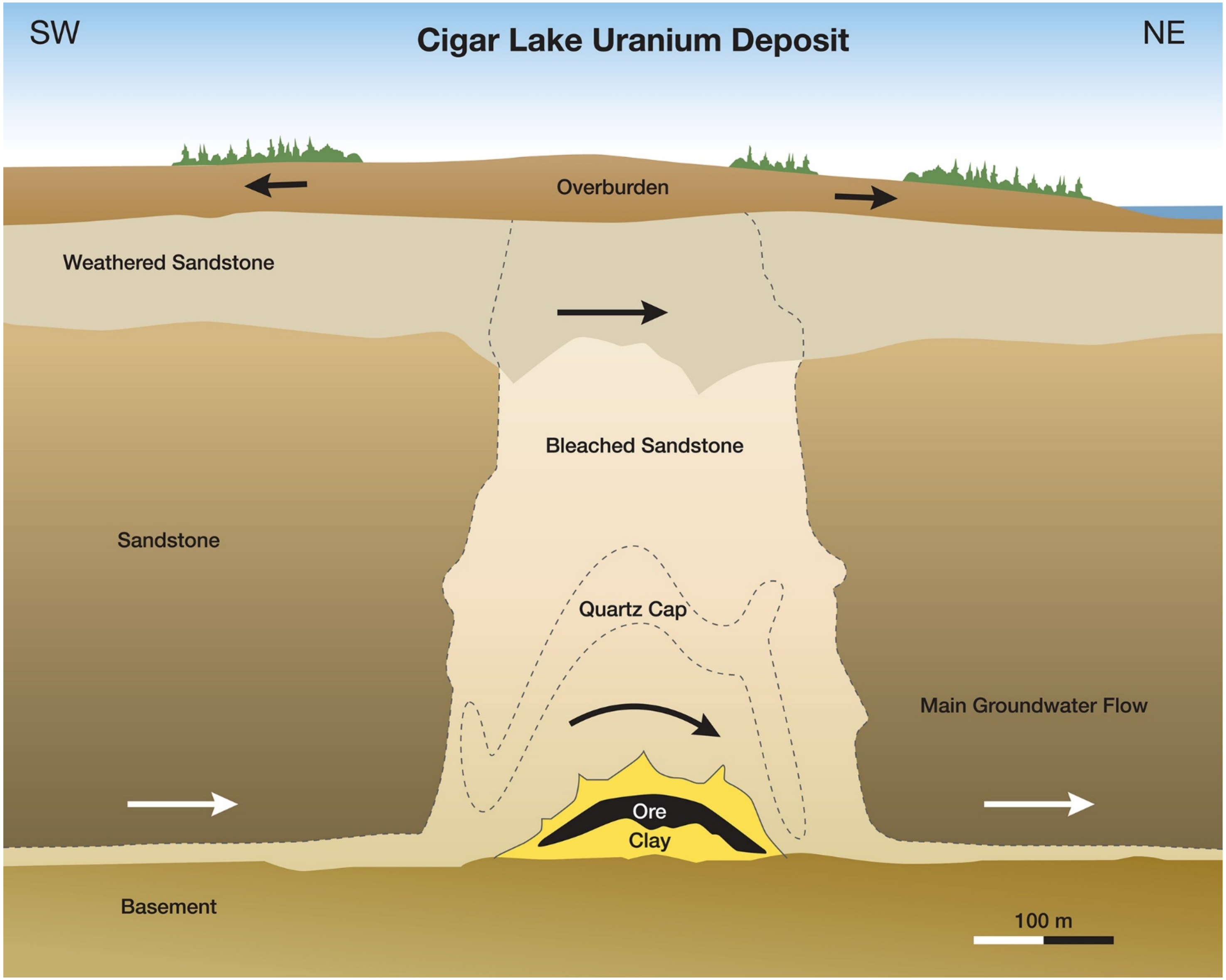


Nature of the Hazard - Radioactivity



Radioactivity of Used CANDU Fuel Relative to Equivalent Uranium Ore

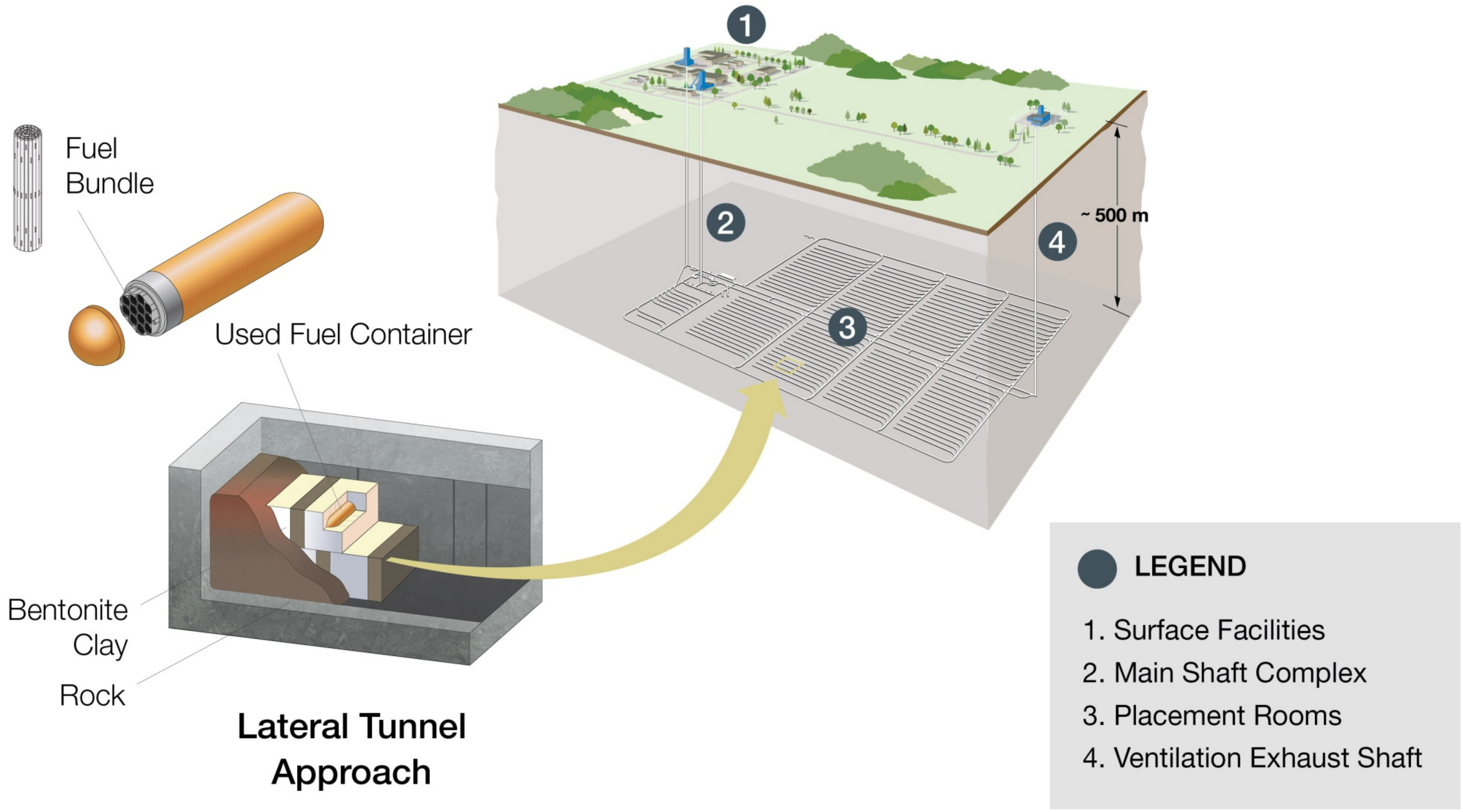
What Can we Learn from Natural Barriers?



The Multi Barrier System

What are the barriers?

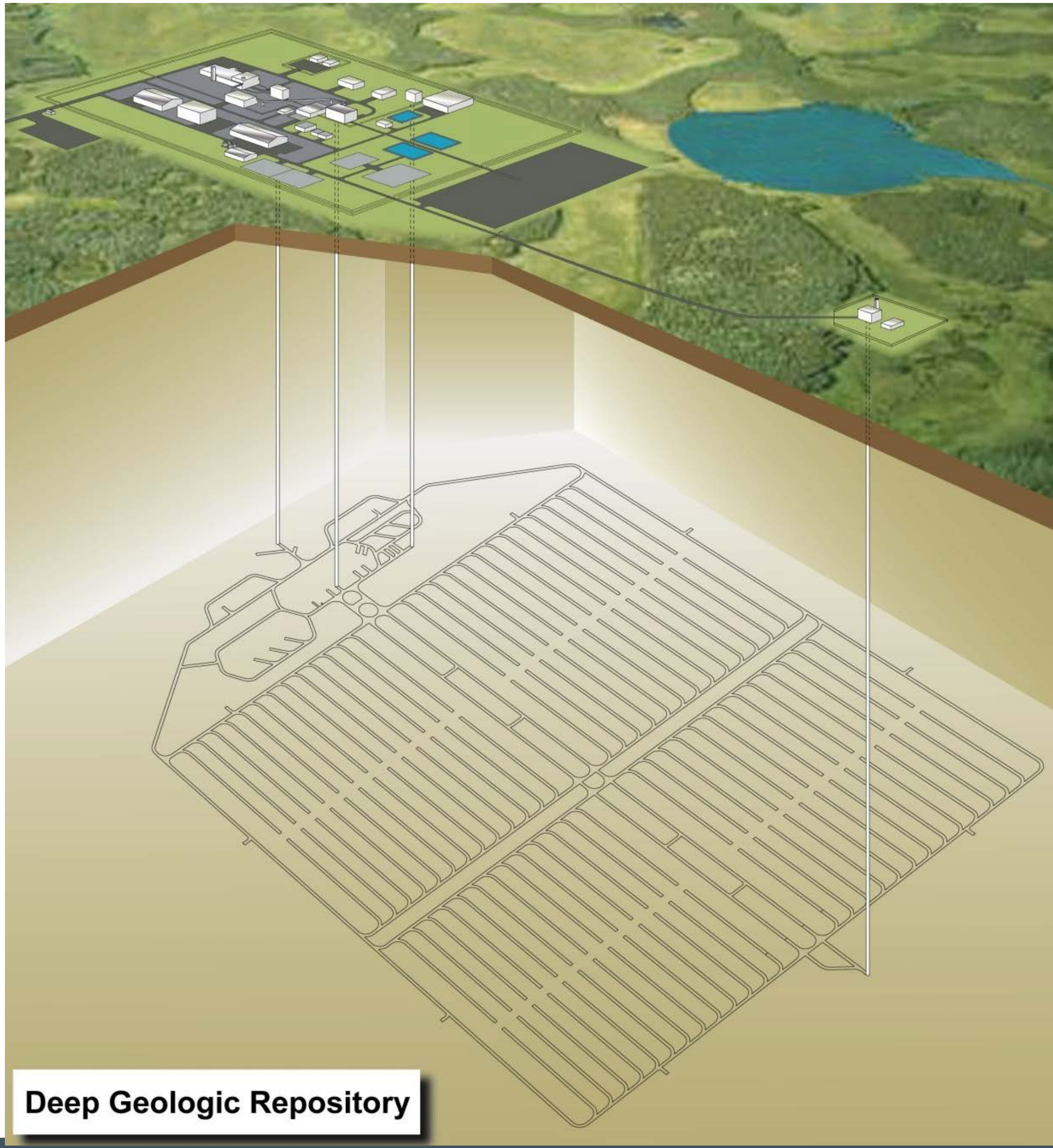
Design is Based on Combination of Engineered and Natural Barriers



Natural Barrier and Wasteform

Natural Barrier: Geosphere (Host Rock)

- The host rock at depth forms a natural barrier.
- It will protect the repository from natural surface events and human activities.
- The host rock will isolate the used fuel from humans and the environment by limiting the movement of radionuclides if other barriers fail.



The Fuel - Why is UO_2 a good barrier

- Hard, high-density ceramic
- Ceramics are extremely long-lived over geological time as they are the stable geological form of metals (i.e. the ores)
- UO_2 dissolution will take millions of years only if it gets wet
- Adding other engineered barriers adds redundancy

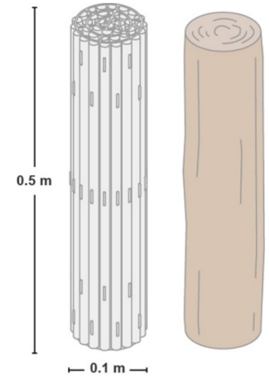
UO_2 ceramic pellet

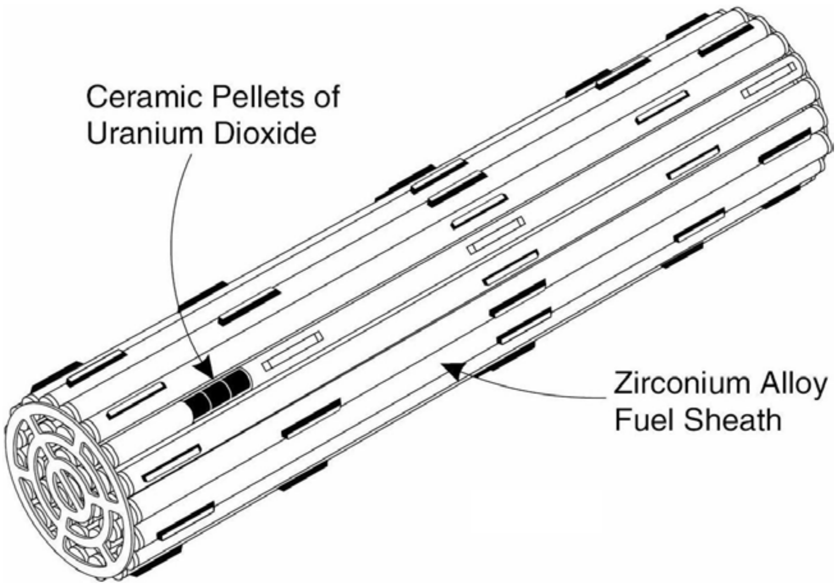
Ceramic tiles on space shuttle

>2500 y old ceramic

Zircaloy Cladding Contains the Fuel

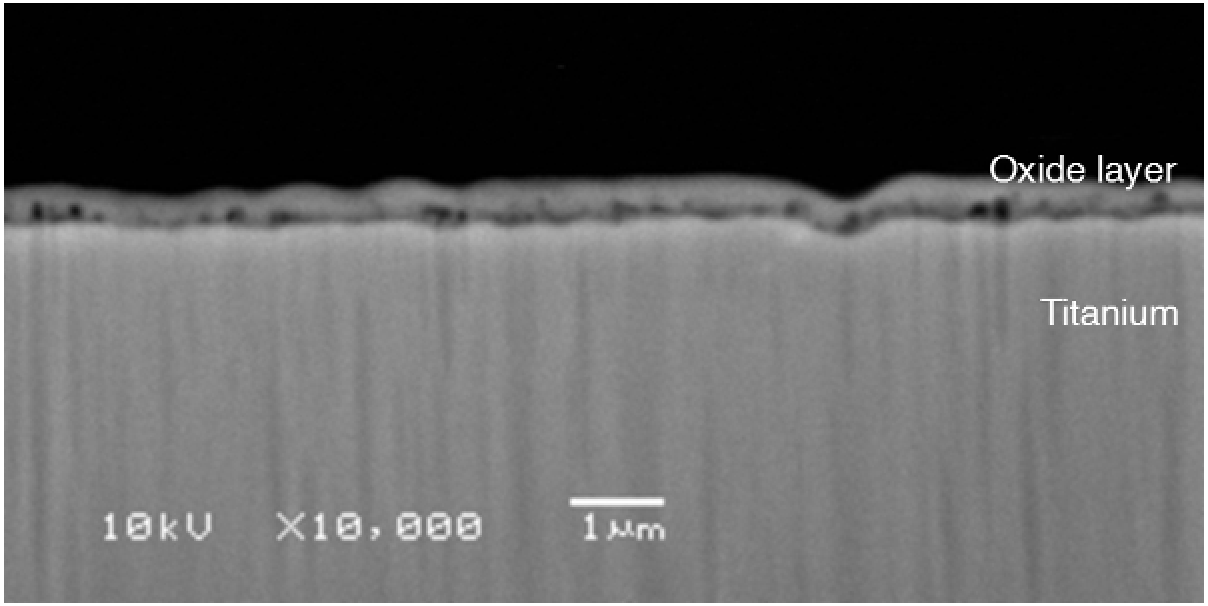
- Used fuel pellets are held in sealed tubes made of Zircaloy (a zirconium alloy).
- Zircaloy is a strong, corrosion-resistant, **passive metal**.





Passive Metals – How do they work?

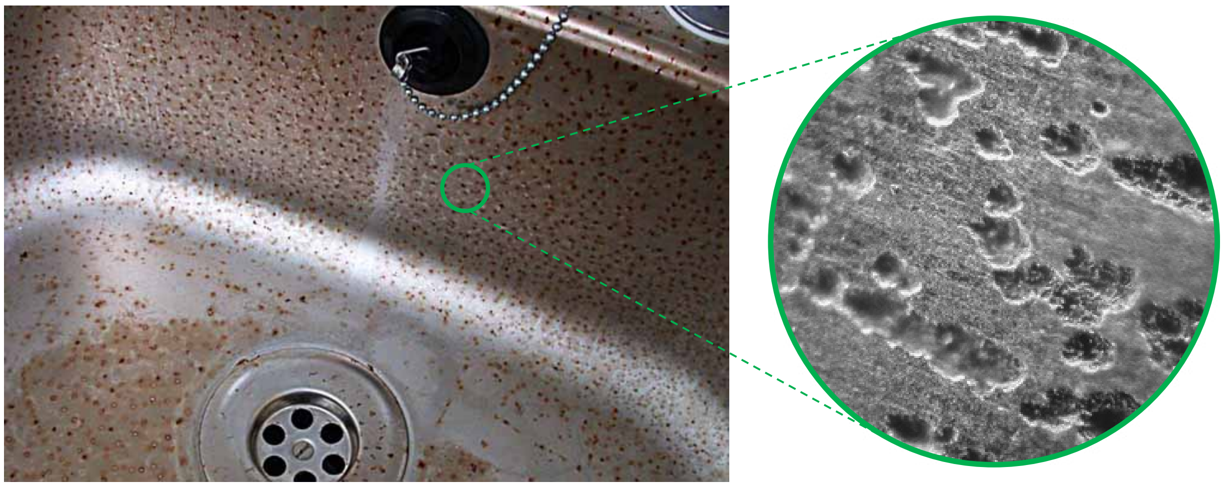
- Passive metals are generally very corrosion resistant due to a protective, compact oxide layer
- However, passive metals are not perfect due to localized corrosion



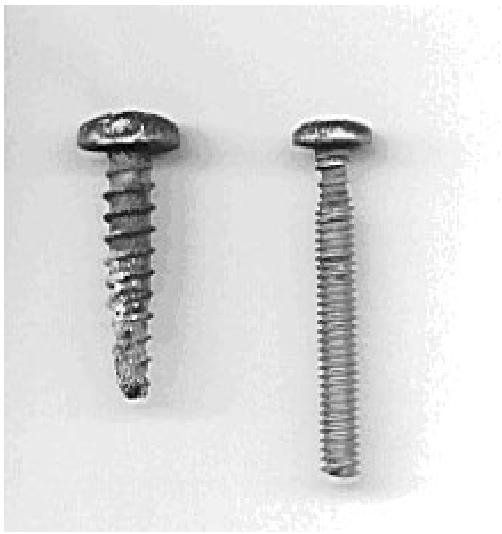
Passive Metals – How do they corrode?

- Localized Corrosion – Pitting and Crevice Corrosion

Stainless Steel Pitting



Ti Crevice



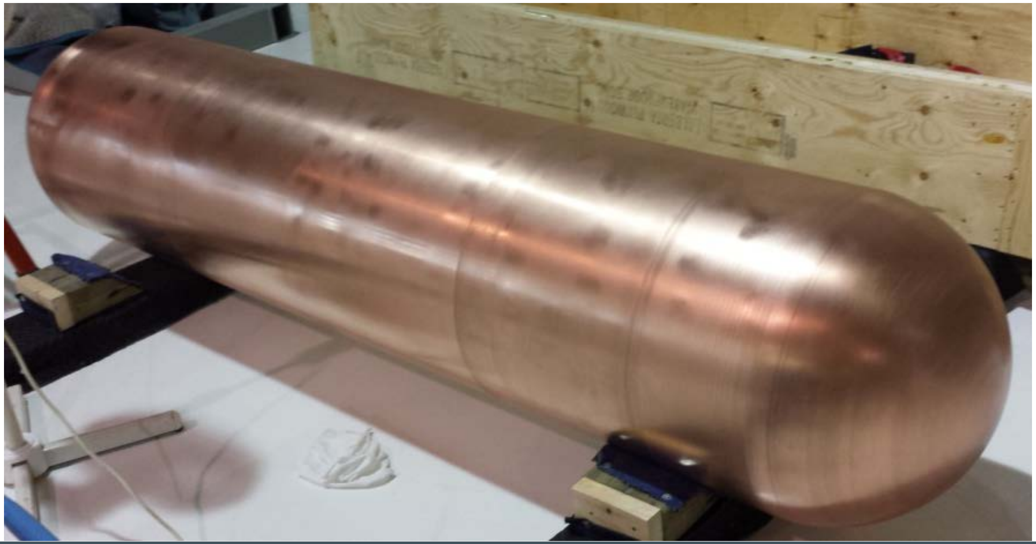
- In the wrong conditions passive metals are prone to localized corrosion

Container and Sealing System

Long-Lived Copper Coated Container

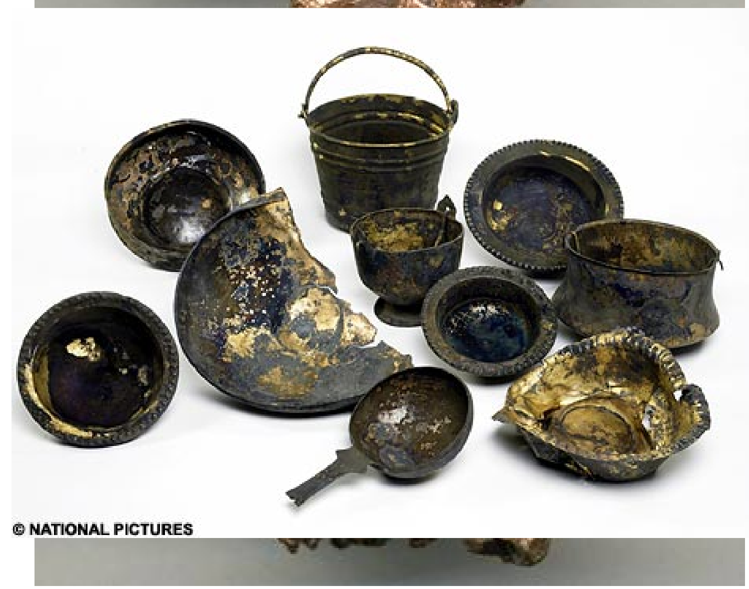
- Carbon steel "core"
- Length= 2.5 m
- Diameter = 0.6 m

- Holds 48 CANDU bundles
- **3 mm copper coating**



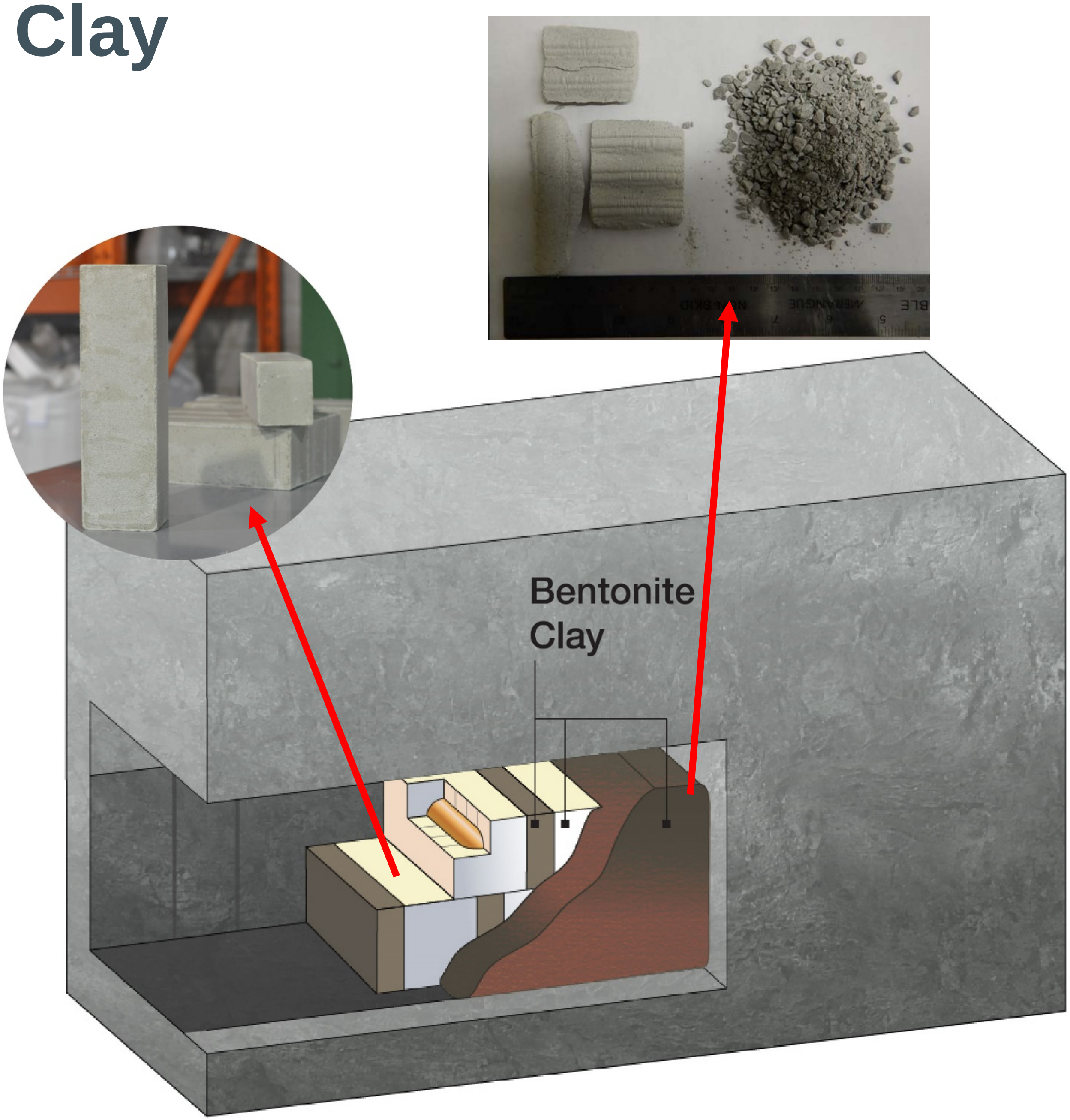
Why Copper for a Used Fuel Container?

- Copper is durable under typical deep geologic conditions (wet oxygen-free)
- *Man-made Artefacts*
  - 300-year old Swedish bronze cannon
  - 1600-year old bronze London tableware
- *Native Copper Deposits*
  - 1 ton million-year old native copper ore

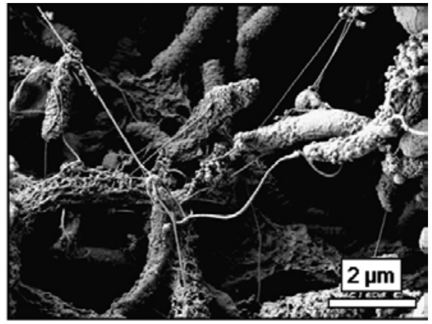


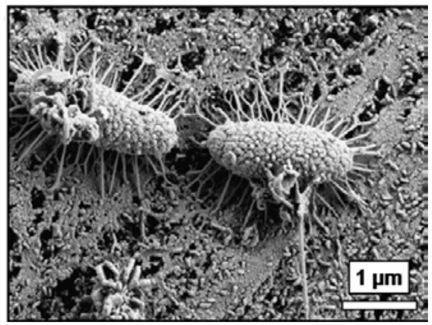
Bentonite Clay

- Used fuel containers, underground tunnels & rooms will be backfilled with bentonite
- Slow natural movement of water through the repository.
- Prevent microbial growth
- If a container fails, clay can chemically slow contaminants.



Why Engineer Against Microbes?

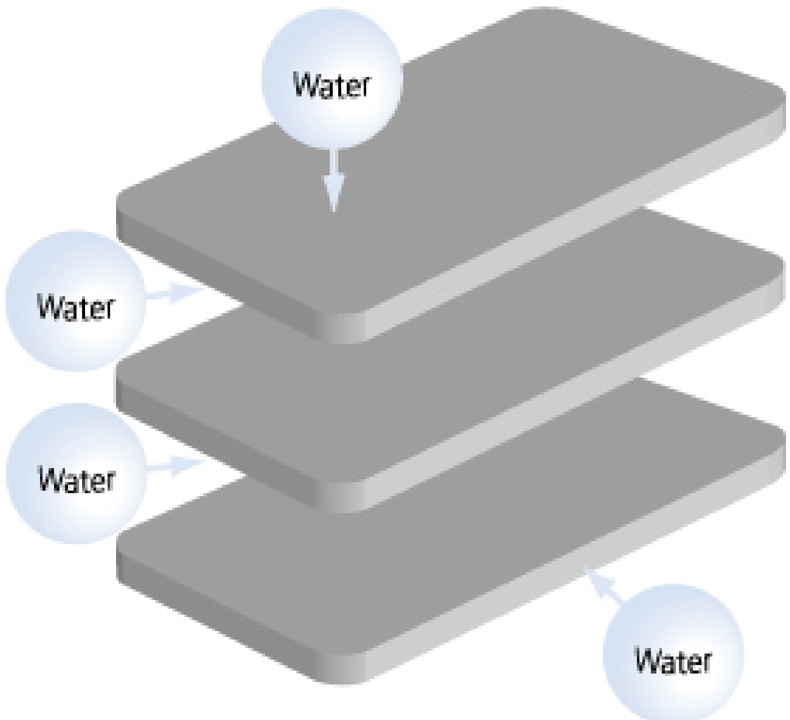




- When biofilms form microbes can produce corrosive chemicals leading to damage

- By swelling, bentonite closes off pores and restricts water from microbes
- Natural analogues show the ability of bentonite to control microbes

Bentonite Swelling: How Does it Work?



Summary

- Multiple barriers give confidence that (permanent) containment is possible for used nuclear fuel
- Engineered barriers are important safety features and are the only ones we design
- Engineered barriers are complimentary to the natural barrier