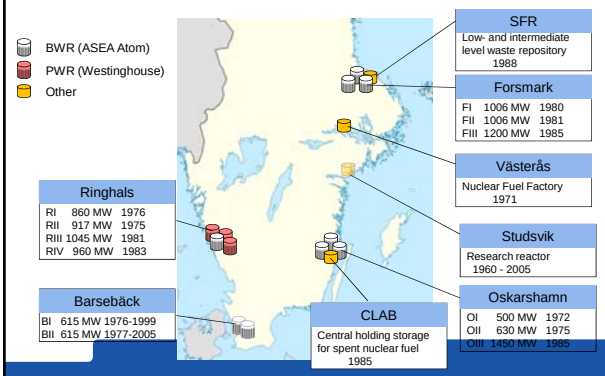
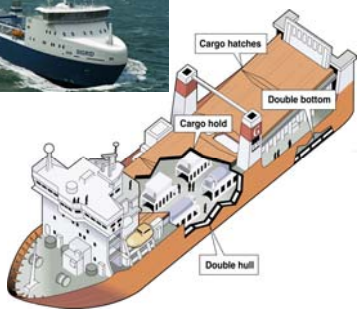
Nuclear Fuel Cycle 2013

Lecture 11: KBS-3, The Swedish Concept for Storing Spent Nuclear Fuel

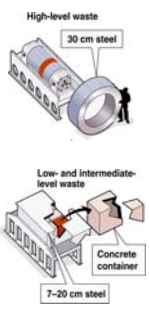
Swedish Nuclear Power System



m/s Sigyn – m/s Sigrid



Transport casks



SFR –Final storage of low level waste

Low active waste from operation of nuclear power plants; clothes, replaced parts from plants, ion exchangers.
Also radioactive material from health care, industry and research.

After 500 years the waste in SFR will not be radioactive

SFR was originally built to last 10 000 years

2010 SFR was extended from 63 000 m^3 to 200 000 m^3.

SFR –Final storage of low level waste

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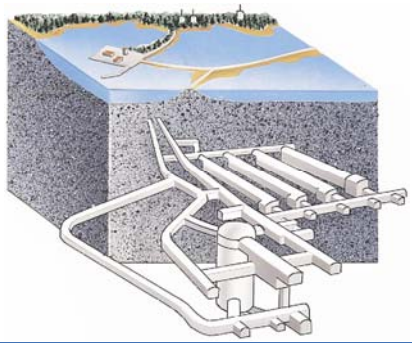


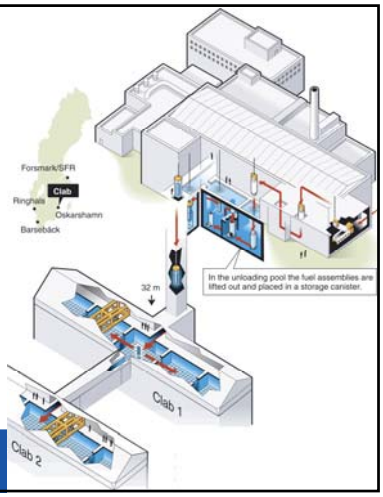
High Level Waste

The waste is stored at the nuclear power plant for one year. During that year the activity of the waste is reduced by 90%

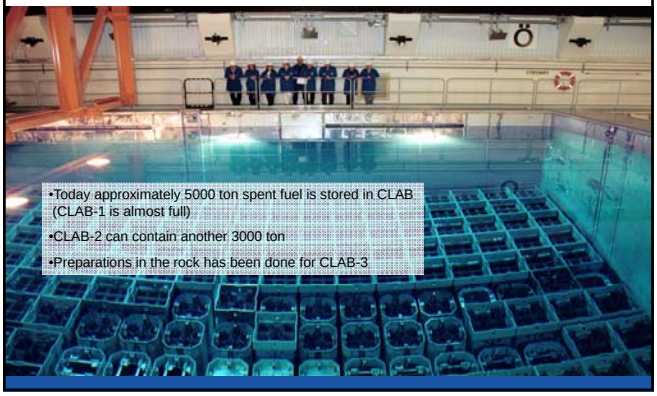
- The waste is transported to CLAB with m/s Sigyn. The waste is stored at CLAB for at least 30 years. During those 30 years the activity is reduced again by 90%.

=> When the waste is placed in the deep repository only 1 % of the original activity remains.

CLAB –Central interim storage for spent nuclear fuel

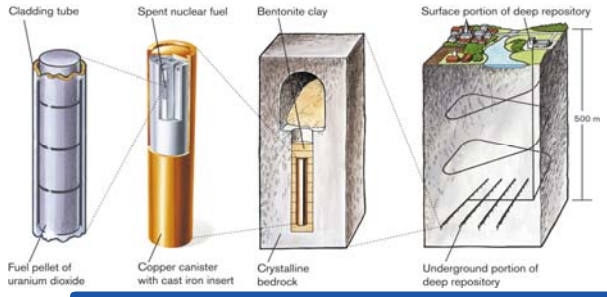


CLAB



- Today approximately 5000 ton spent fuel is stored in CLAB (CLAB-1 is almost full)
- CLAB-2 can contain another 3000 ton
- Preparations in the rock has been done for CLAB-3

KBS-3: The Swedish Concept of Storing Spent Nuclear Fuel



KBS-3: Presumptions

The repository shall keep the spent fuel from reaching the biosphere for >100 000 years

⇒ All processes need to be extrapolated to extreme times.

⇒ The models must be based on thermodymanically stable processes

The Fuel itself

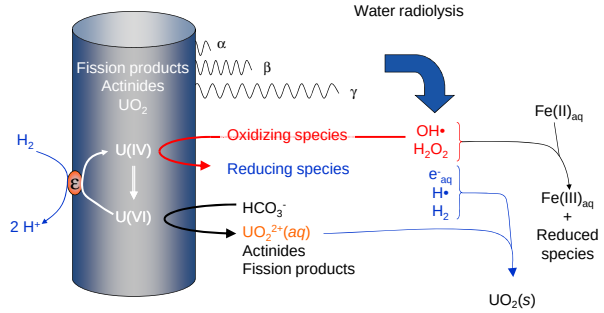
The spent fuel is 95% UO_2

Fission products and actinides are all incorporated in the UO_2-matrix

=> The release rate depends on the dissolution rate of UO_2

Under reducing conditions the solubility of UO_2 is very low (10^{-9} M)

Dissolution of the Fuel



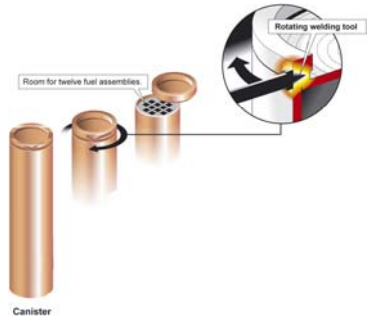
The copper canister

Inner cask of cast iron (support) and 5 cm Cu (chemical resistance)

Under reducing conditions corrosion of copper is a very slow process

Recently copper has been questioned as material.

Welding the cap



Critizism

Researchers claim that they have performed experiments where Cu corrodes in oxygen-free water
They claim that the canister may collapse in 1000 years

- If Cu would corrode in oxygen-free water an yet undiscovered Cu(I)-phase must exist

- Another recent study suggests that Cu will corrode faster after being exposed to ionizing radiation

Bentonite Clay

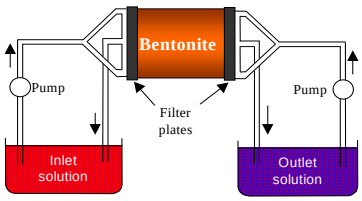
70-80% is montmorillonite

Montmorillonite takes up water and swells (swelling pressures up to 100 bars)

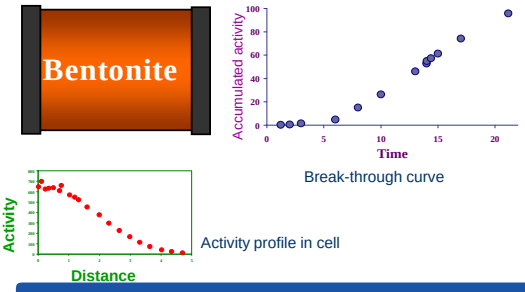
All transport to and from canister will be by diffusion

The clay is a plastic material. It will take up movements in the rock.

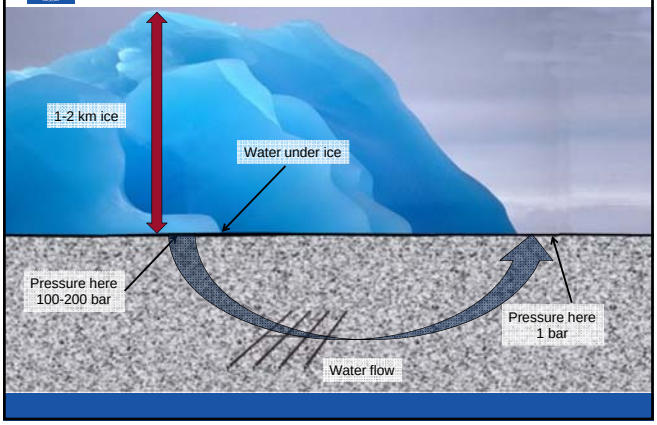
Determining transport properties of bentonite clay



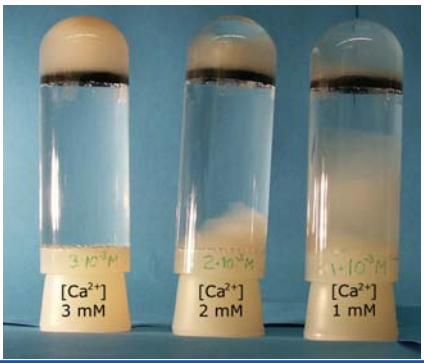
Obtained data

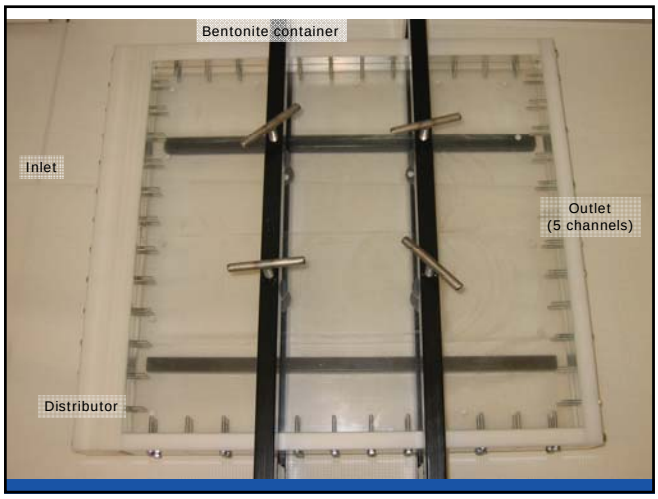


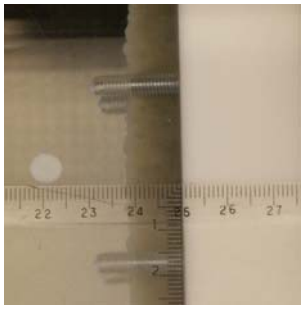
The Ice Age Scenario



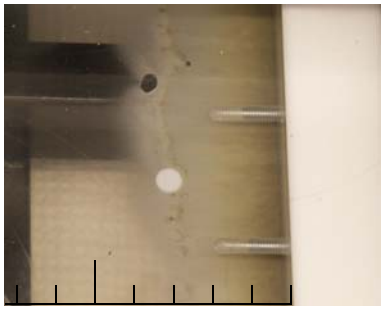
Stability of bentonite vs salinity



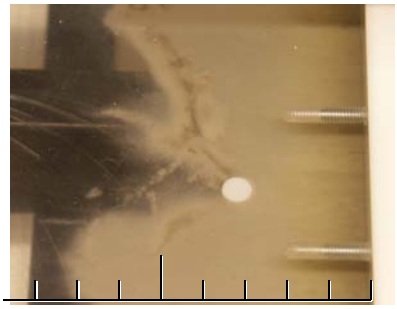




After water saturation of clay



After pumping distilled water
in fracture water 4 weeks



After pumping in fracture water 28 weeks

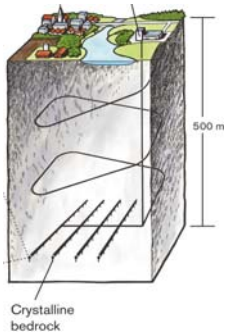
After pumping in fracture water 45 weeks

Conclusion

Bentonite may disperse if water with sufficiently low salinity penetrates the repository.

Other studies show that benonite colloids may facilitate faster transport through bed-rock

The Bedrock



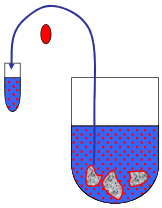
Most radionuclides in the fuel are cations.

Most mineral surfaces are negatively charged.

The transport towards the biosphere the cations will be largely retarded by sorption to the bedrock

Sorption properties of the rock

Determination of Sr-distribution between granite and solution



Water

Add granite

Add tracer (cation to study)

Wait for equilibrium

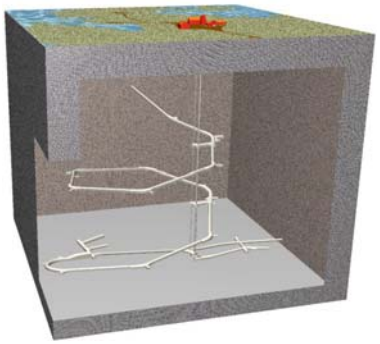
Take sample from solution

In-Situ Studies

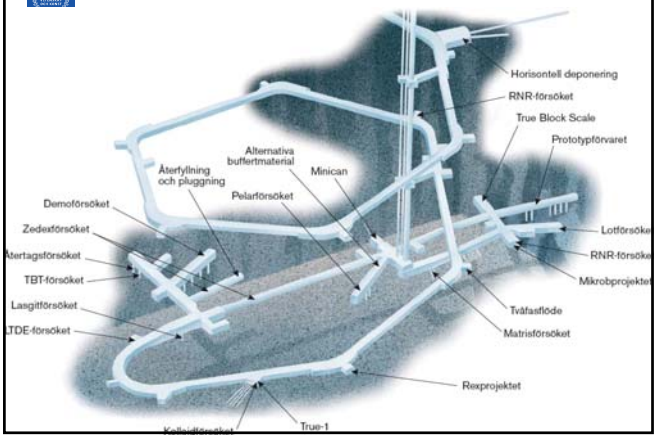
Äspö Hard Rock Laboratory

Äspö HRL Facility

- Office space for 86 persons
- Main experimental area between 220 and 450 m levels
- Rescue chamber/ conference room on 420 m level
- Hoist and 2 ventilation shafts
- On-line hydro-monitoring system



Experiments at Äspö HRL



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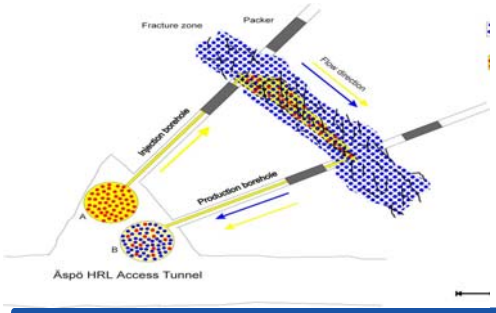
Tracer Retention Understanding Experiments



RNR: CHEMLAB

RadioNuclide Retention

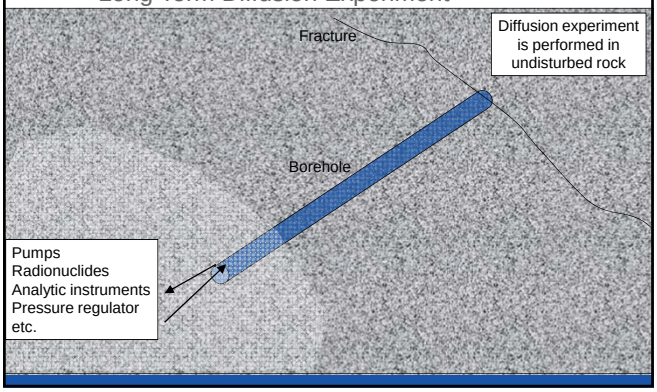
RNR: CHEMLAB

RadioNuclide Retention

- Diffusion of radionuclides in bentonite clay
- Study the influence of direct and indirect radiolysis on the migration of Technetium
- Migration of actinides through a rock fracture

LTDE

Long Term Diffusion Experiment



LOT

Long Term Test of Buffer Material

Bentonite clay was tested under adverse conditions

In one of the blocks radionuclides were added

The blocks was retrieved and sliced up

The activity profile in the block revealed the diffusional behavior of the radionuclide

Selecting the site

Pre-studies have been performed in 8 communities

The first ones were in the Northern part of Sweden; Malå, Storuman, Älvkarleby.

Later Tierp, Nyköping, Hultsfred, Oskarshamn and Östhammar

- Referendum were held in Malå where the people said no (54%)
- Later politicians in Älvkarleby, Storuman and Tierp said no

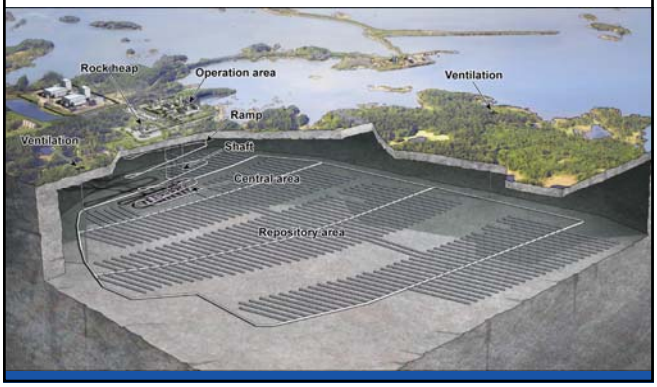
Selecting the site

Eventually SKB choose Oskarshamn and Östhammar for more detailed site investigations.

- 2010 SKB announced that Östhammar was selected

- Very solid bed rock, few fractures, little water.
  - The bentonite clay will not disperse.
  - Canisters may corrode due to sulphide. This corrosion will be limited with limited water supply
  - Construction will be easier with limited water
- Stress in rock greater in Östhammar but will not influence greatly
- Care has to be taken to a certain toad living in Östhammar.

Deep Repository in Östhammar



How much are we talking about?