Swedish Nuclear Fuel and Waste Management Company (SKB)

Äspö Hard Rock Laboratory

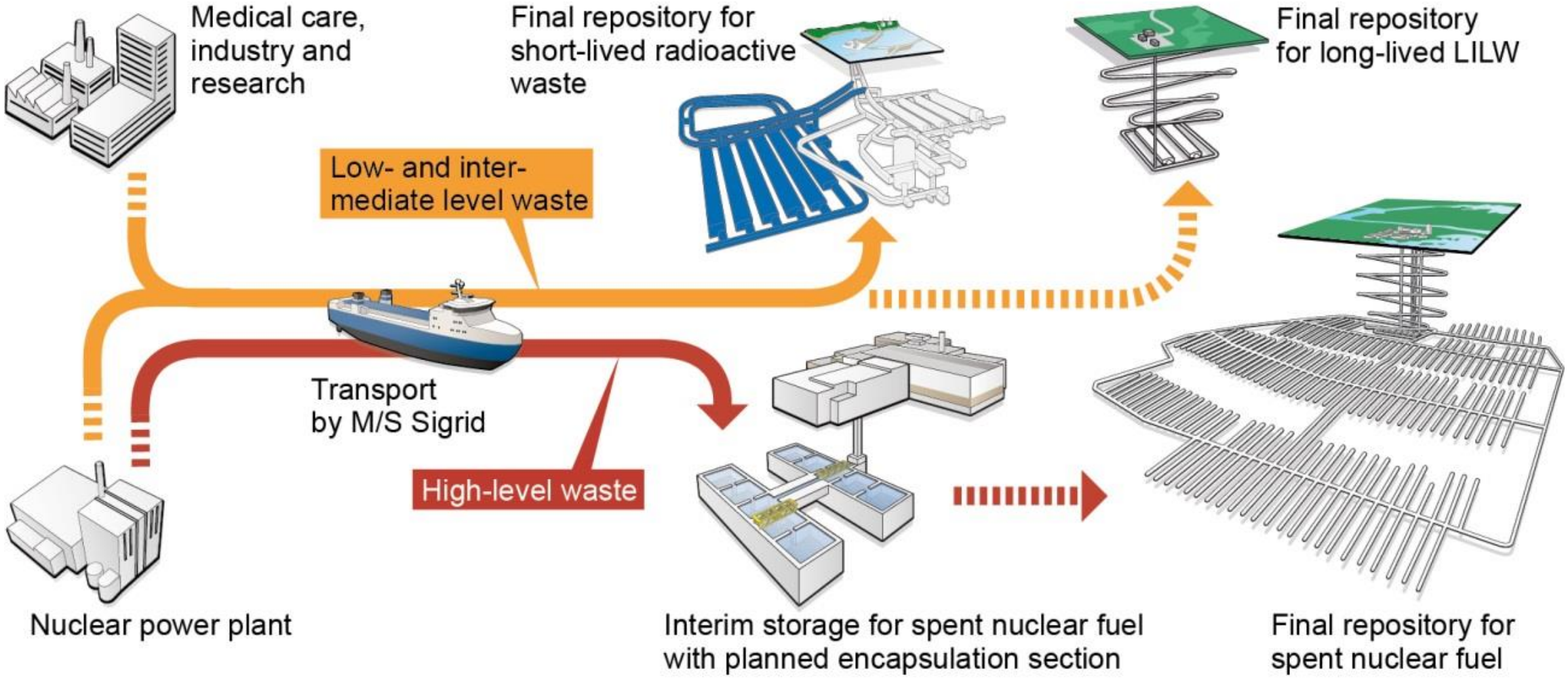
“Äspö has been the place where all method development for the execution and evaluation of site investigations has been carried out, all research concerning long-term safety for the natural barrier and the development of clay barriers has been carried out. And the development and demonstration of methods for repository design and deposition.” / Peter Wikberg

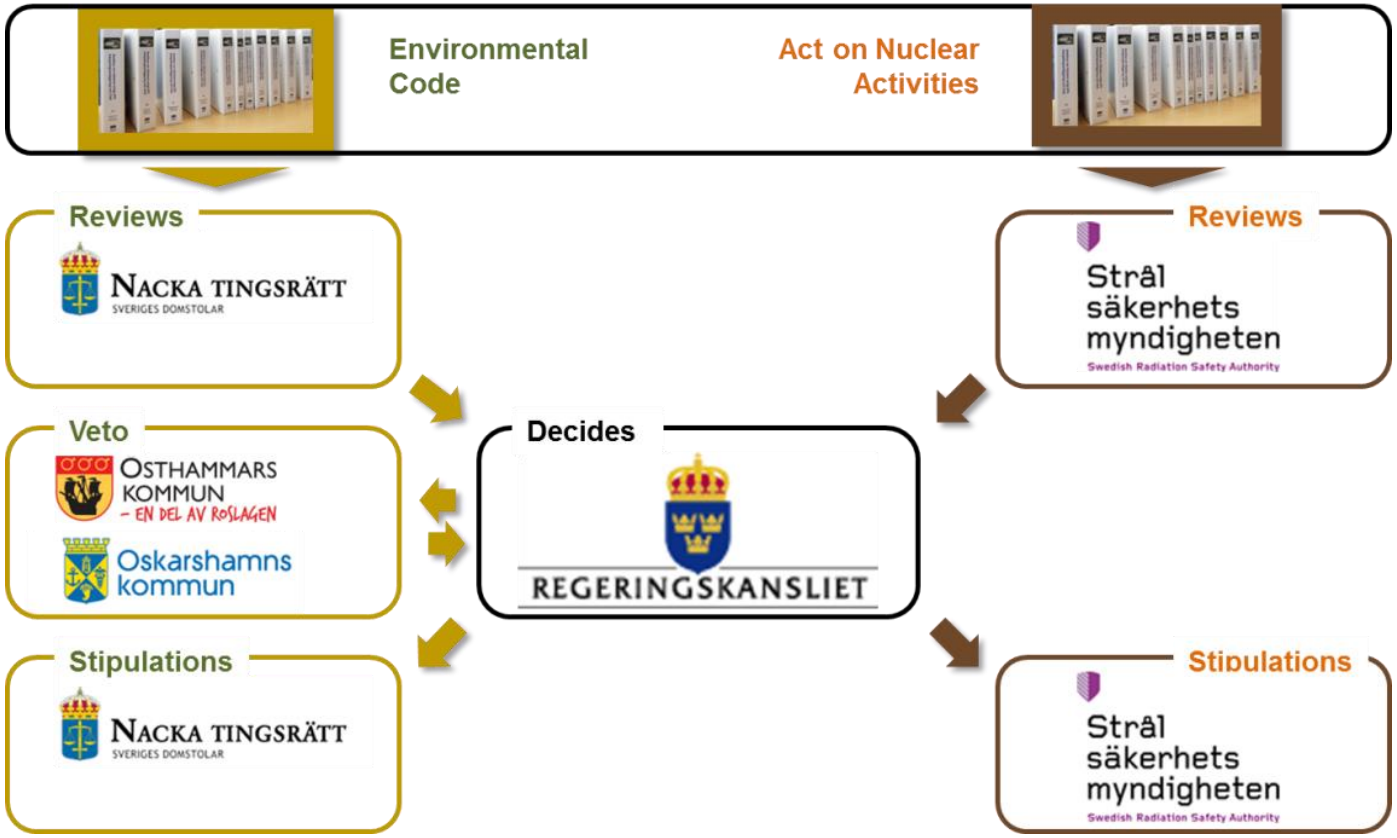
Patrik Vidstrand

Outline

- **Background**
  - **The Swedish waste system**
  - **Safety Assessment**
  - **Data and information for the safety assessment**
  - **The KBS-3 concept**
  - **The Forsmark site**
  - **SKB Organization**
- **The Swedish URL**
  - **History**
  - **Äspö HRL**
  - **Examples**
  - **Concluding**

The Swedish waste system





The assessment should answer the question “Is the repository safe in the long term?”

Methods for analysis developed through international cooperation

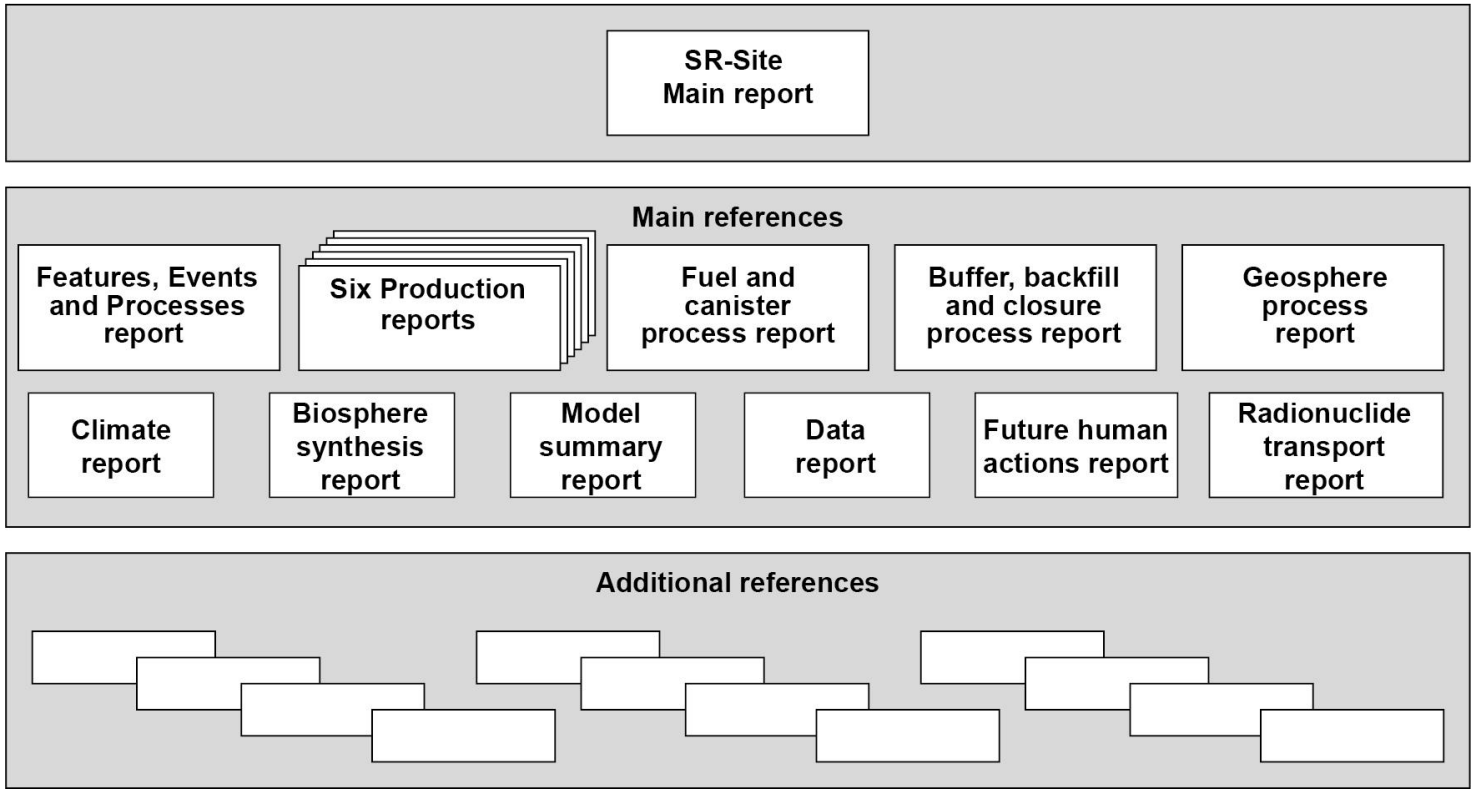
But every country needs to find its own “dialect” to suit national legislation, geological conditions, repository concept, etc.

In Sweden, relevant regulations by the Swedish Radiation Safety Authority, SSM, establishes what society considers as “safe”

The safety assessment SR-Site

- Supports SKB's license application for a final repository at Forsmark, submitted in 2011
- Based on the KBS-3 concept
- At the Forsmark site

- Document structure
  - Main report, about 900 pages, SKB TR-11-01
    - 40 page summary
    - 15 chapters in three volumes
  - 16 main references
  - About 100 additional references
  - All reports available at www.skb.se

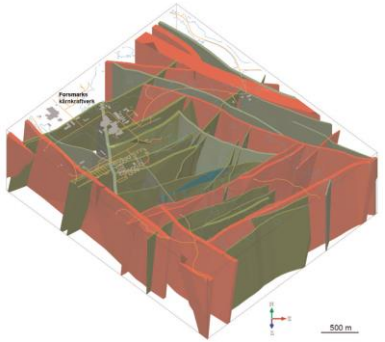


Data and information for the safety assessment

A. **Basic science**

$$M^k(t) = M_0^k \exp(-\lambda_k t) + \sum_{l=1}^{k-1} \left\{ M_l^0 \left\{ \prod_{j=1}^{k-1} \lambda_j \right\} \left[\sum_{j=1}^{k} \frac{\exp(-\lambda_j t)}{\prod_{\substack{n=l \\ n \neq j}}^{k} \lambda_n - \lambda_j} \right] \right\}$$

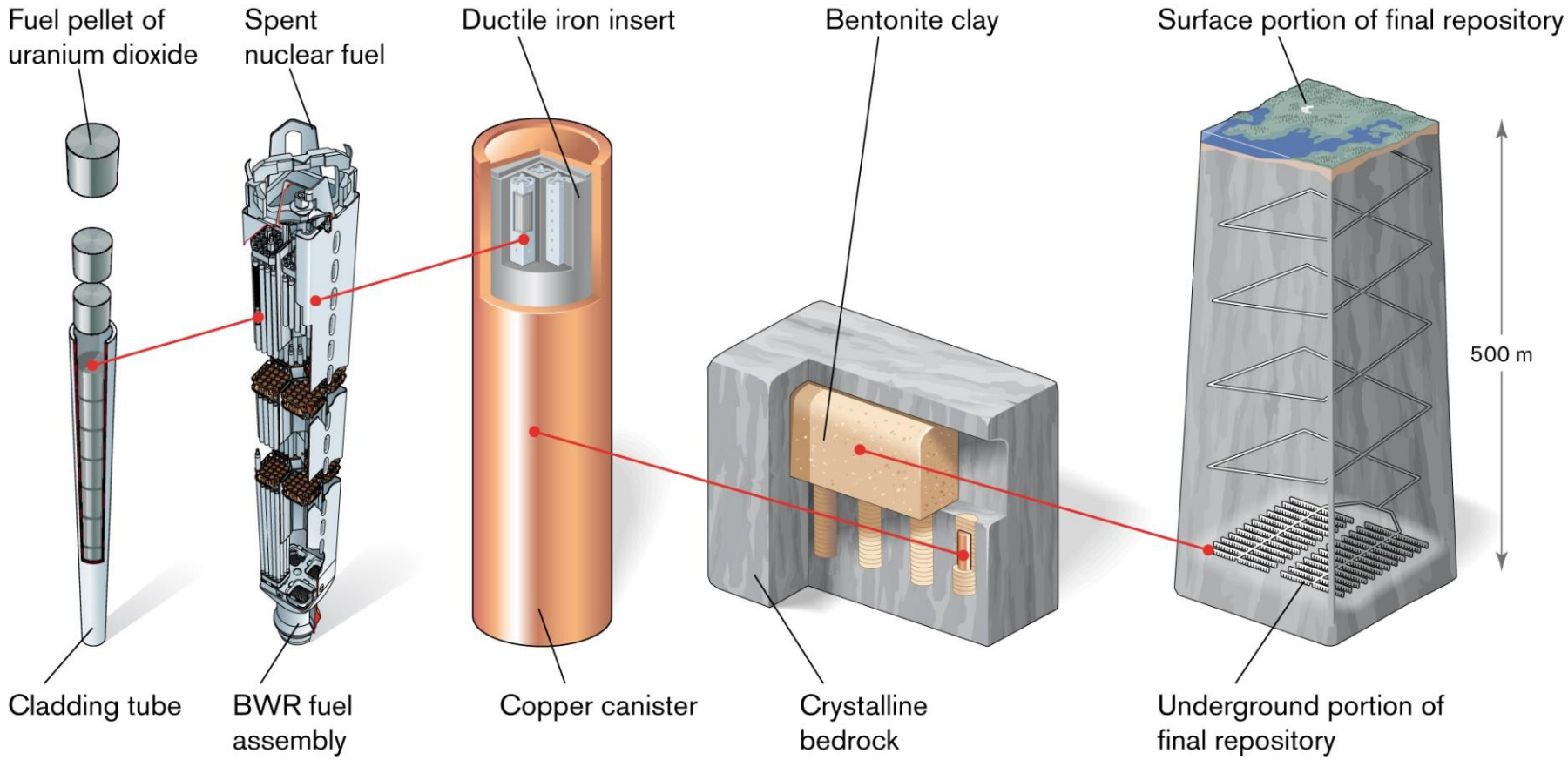
B. **More specific knowledge to apply basic science to repository conditions**



C. **The properties of the site**

D. **The engineered barriers' properties at deposition**

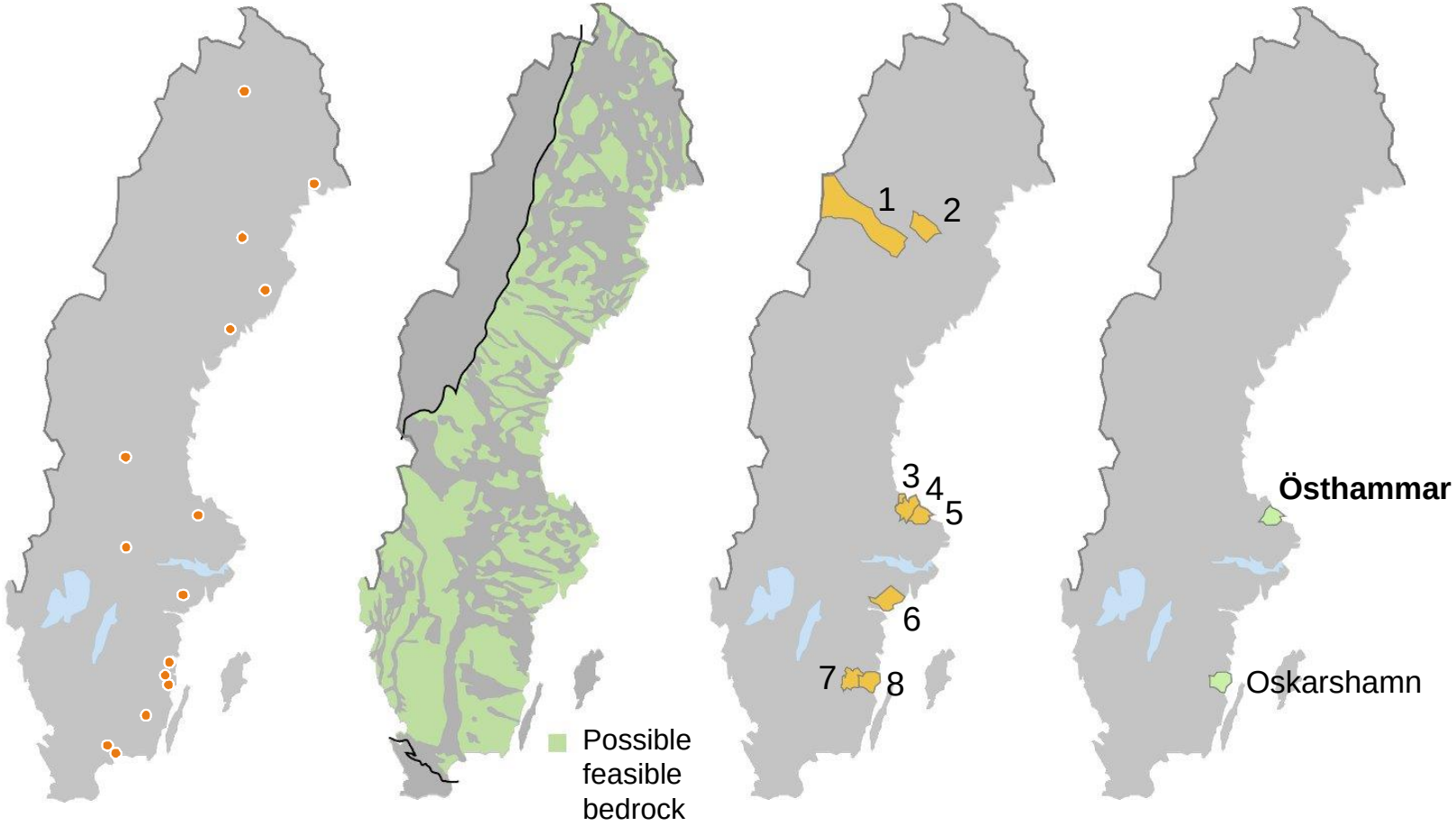
The KBS-3 concept



Primary safety function: Complete containment

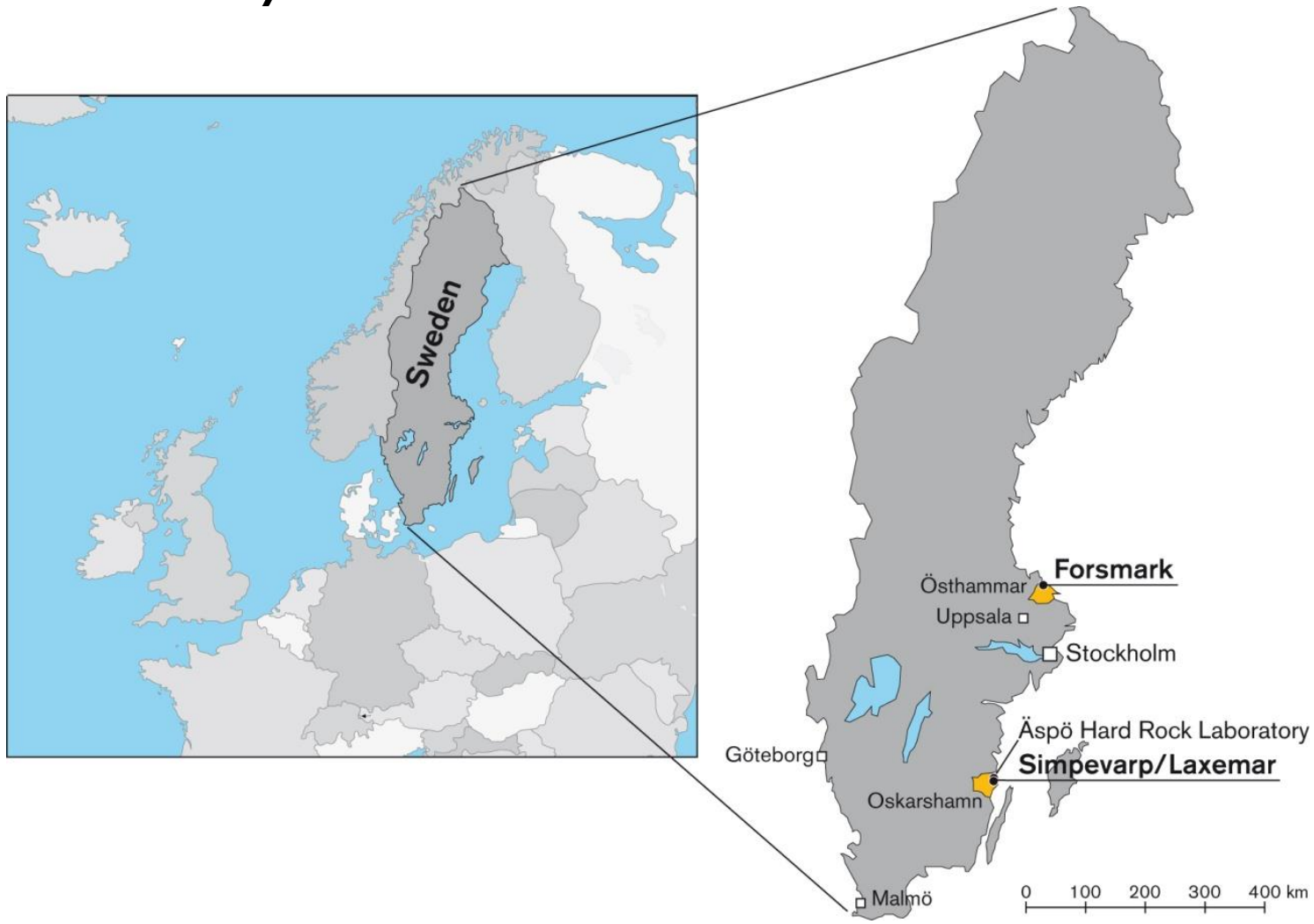
Secondary safety function: Retardation

Siting studies 1977-2009
”Geology and society”



The Forsmark site (Östhammar)

- Selected in 2009 after seven years of surface based site investigations and site modelling at Forsmark and Oskarshamn/Laxemar
- A comprehensive site description, including a coupled Thermo-Hydro- Mechanical-Chemical model of the site published in 2009 forms the technical and scientific basis for the handling of the site in the safety assessment



The Forsmark site

- Geology
  - Relatively homogeneous
  - Steeply and gently dipping deformation zones
- Rock mechanics
  - Rock stress relatively high compared to typical levels in Swedish bedrock
- Hydrogeology
  - Highly transmissive fractures close to the ground
  - Very few transmissive fractures at depth
- Groundwater composition
  - Fresh water only at shallow depth
  - Salinity increases with depth
- Site described in technical report (TR-08-05)

What does the repository look like initially?

The rock: Knowledge through site investigations and geoscience

- Today: Data from surface based investigations
  - Data and interpretations used to build site descriptive model
- Next stage: More detailed data collected during excavation of the repository

Engineered components: Specifications of canister, buffer, backfill etc.

- Today: Reference design, test manufacturing, plans for quality control
- Next stage: Successively more experience from test manufacturing and quality control

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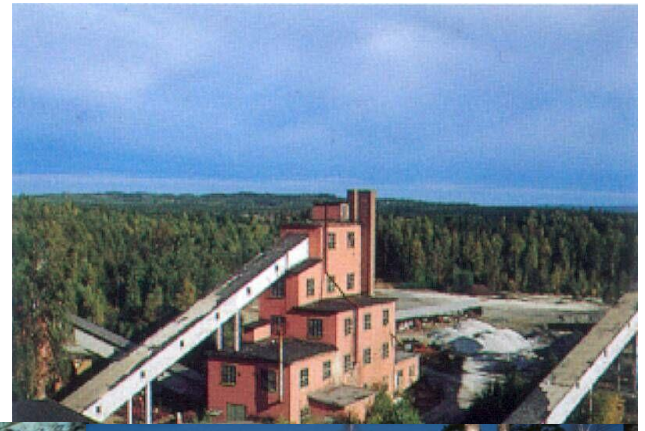
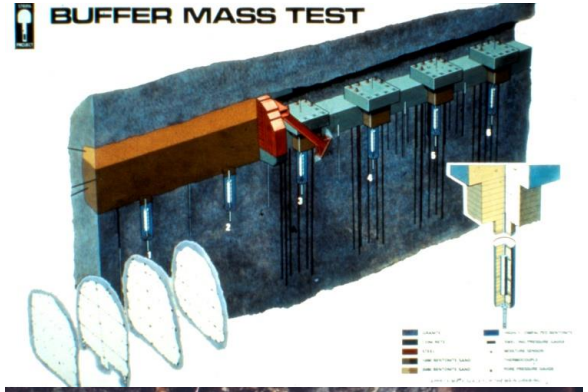
The Swedish-American Cooperative (SAC) program, 1977-1980, The Stripa mine

- evaluating the response of granite to elevated temperature in a simulated repository environment
- developing techniques for characterising the hydrological and mechanical characteristics of naturally fractured granitic rock masses



The International Stripa Project, 1980-1992

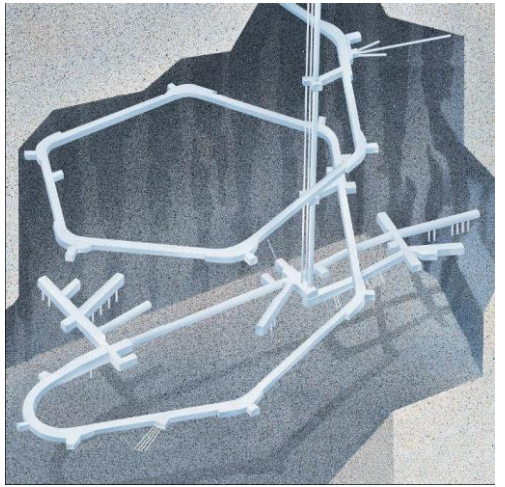
- Participating countries
  - Canada
  - Finland
  - France (Phases 1 and 2)
  - Japan
  - Spain (Phase 2)
  - Sweden
  - Switzerland
  - United Kingdom (Phases 2 and 3)
  - United States
- Managerial oversight by
  - Joint Technical Committee (JTC)
  - Technical Subgroup (TSG)
- Task Forces on
  - Sealing materials and techniques
  - Fracture flow modelling



The Äspö research village!

The first steps toward Äspö SKB's RD&D program 1986

- In September 1986 SKB presented the first RD&D Program according to the new Act on Nuclear Activities.
- One of the major highlights of the program was the plan for the construction of an URL.
- The main aim was to provide an opportunity for research, development and demonstration in a realistic and undisturbed rock environment down to the depth planned for the future final repository.

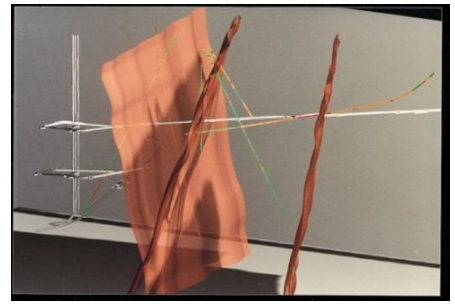


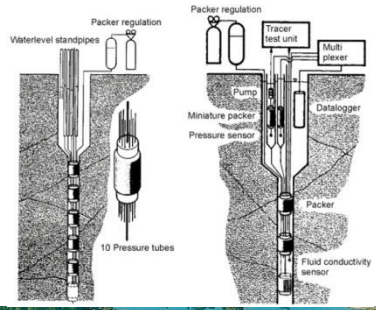
Vital decisions taken in 1986

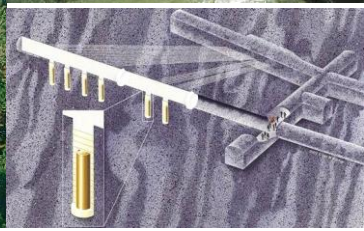
- The use of the underground laboratory is only for research purposes.
- The laboratory will not be converted into a repository in the future!
- Suitable geology, existing infrastructure and service should be available. To begin with, the suitability of one of the nuclear power sites, especially the regional area around Simpevarp in the municipality of Oskarshamn should be explored.

Äspö HRL – Phases of realization

- Pre-investigations 1986-1990
  - Regional geological investigations
  - Surface and borehole investigations
  - Predictions
- Construction 1990-1995
  - Evaluation of predictions
  - Methodology for detailed characterisation
  - Modelling of groundwater flow
- Operating Phase 1995-
  - Test models describing the barrier function of the rock
  - Demonstrate technology and function of the repository system



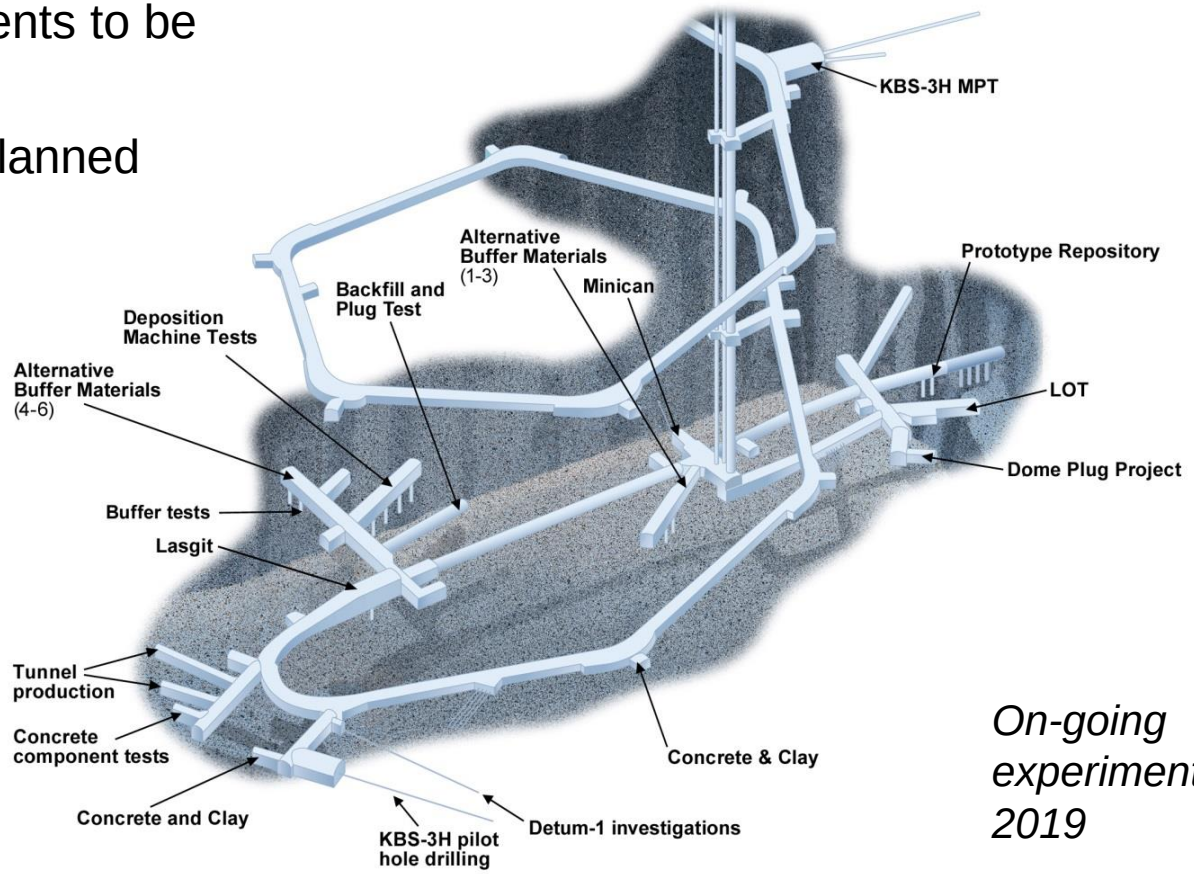




Äspö Hard Rock Laboratory

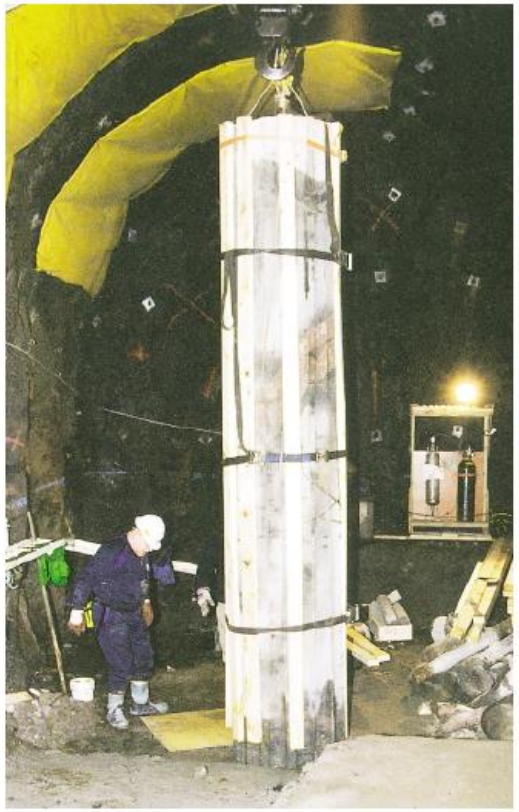
- SKB's RD&D program includes full-time activities in the rock laboratory until the end of 2023:
  - Approximately 15 ongoing experiments to be interrupted and evaluated
  - Several new large-scale tests are planned

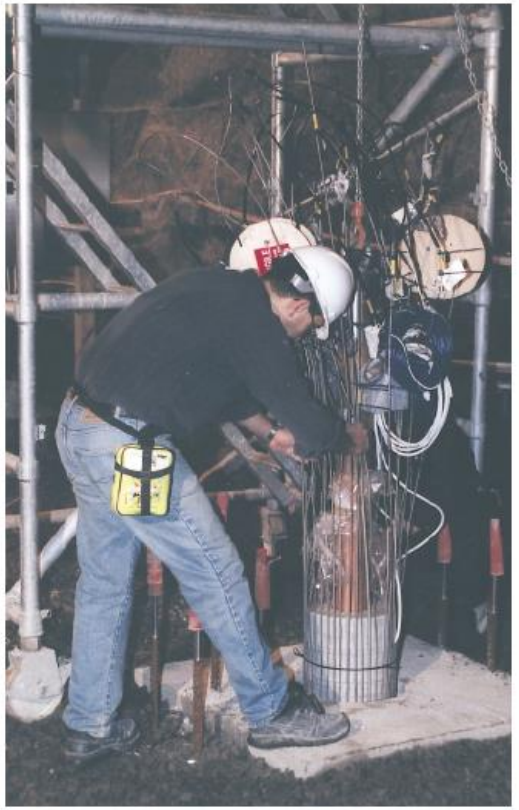
- An international meeting point:
  - SKB International with five partner organizations
  - External and joint projects
  - Training courses



On-going experiments 2019

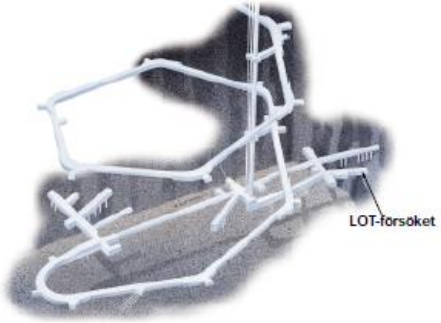
LOT-försöket – Long Term Test of Buffer Material



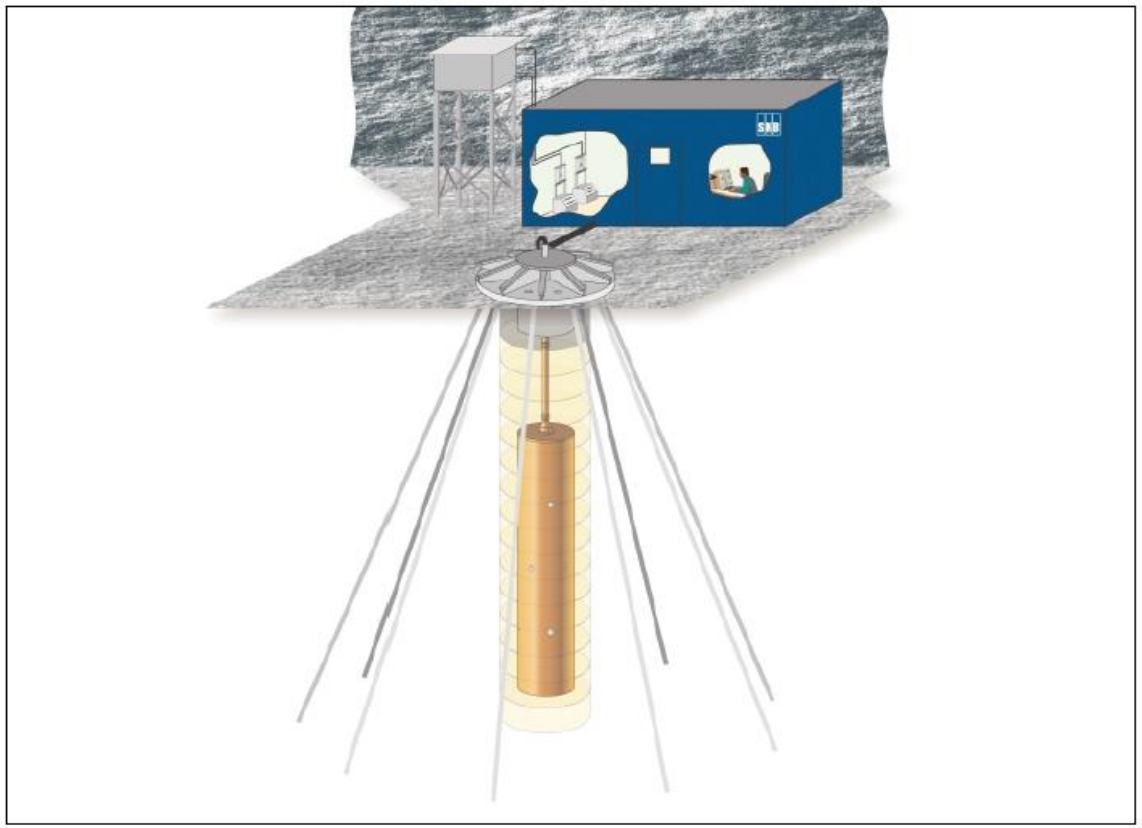


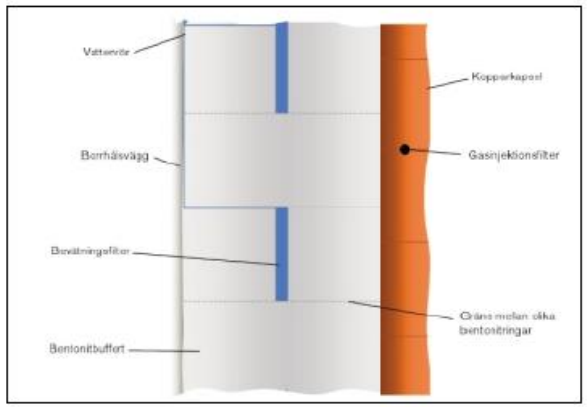
LOT-försöket ska ge svar på frågan hur bentonitleran uppför sig i en miljö som liknar det framtida djupförvaret.

The LOT experiment is intended to show how the bentonite clay behaves in an environment similar to that in the future deep repository.



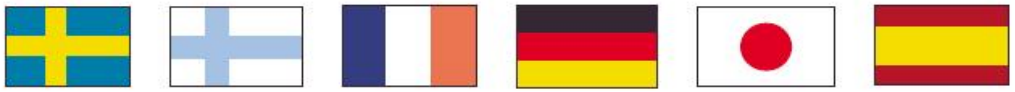
LASGIT – Large Scale Gas Injection Test

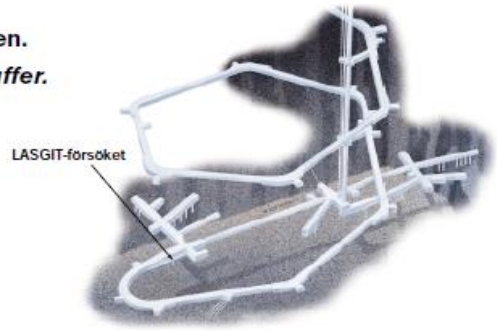




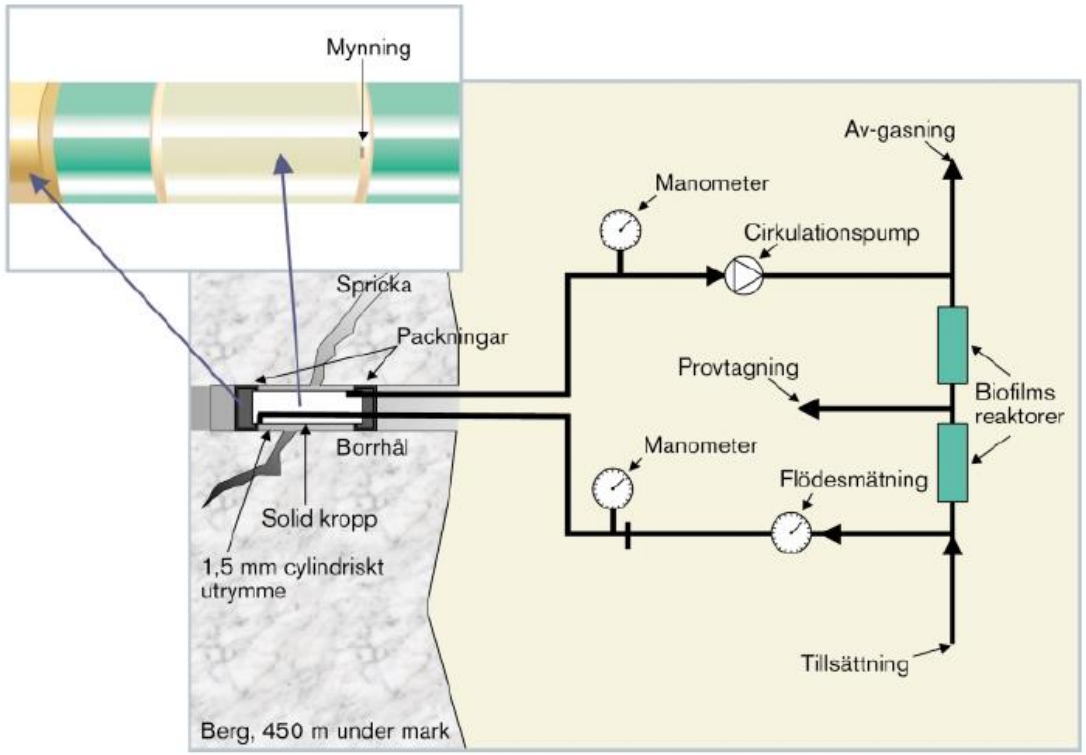
Genom att trycksätta en kapsel med helium kan vi mäta hur gasen tar sig igenom den omgivande bufferten.

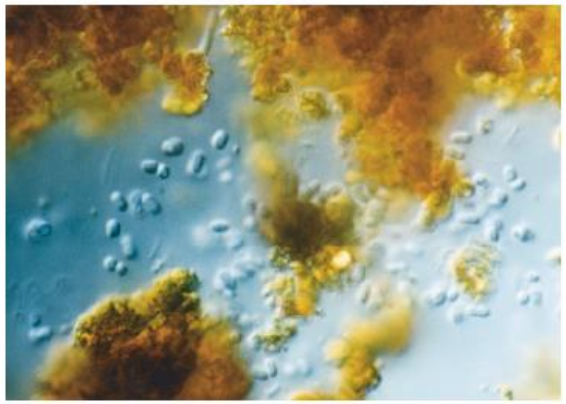
By pressurizing a canister with helium, we can measure how the gas moves through the surrounding buffer.





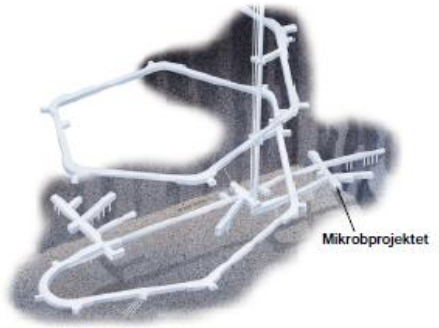
Mikrobprojektet – Microbe Project



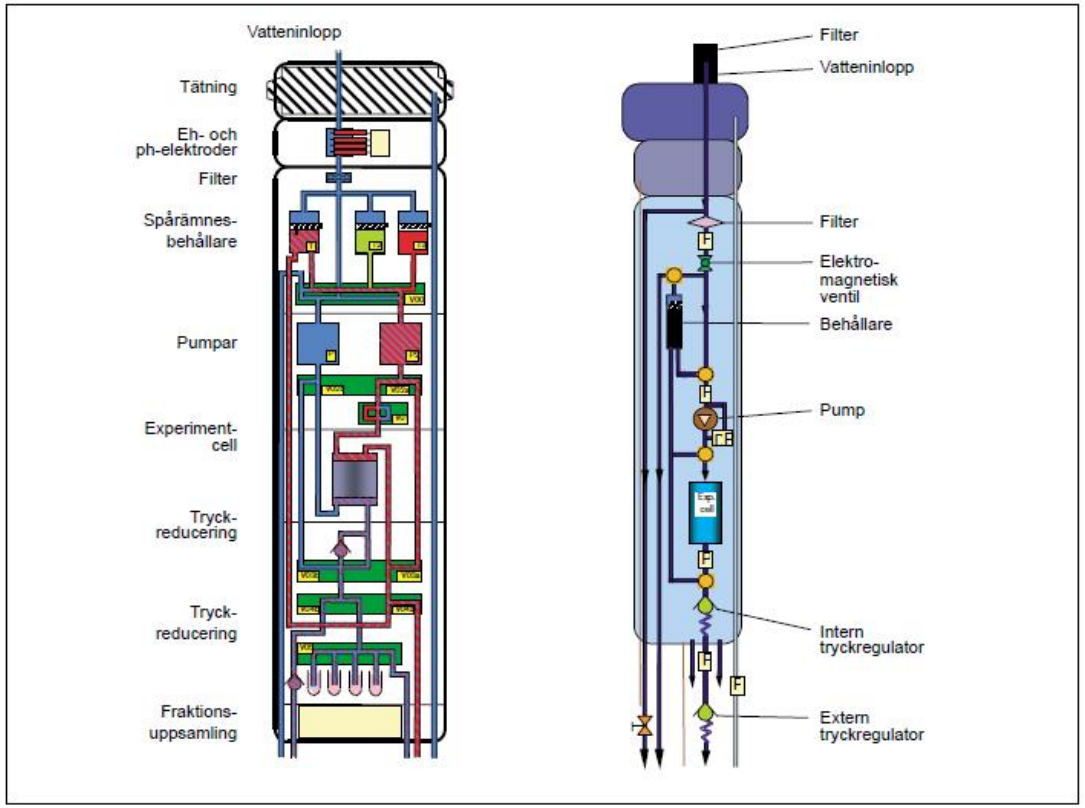


Underjordiska mikrober förbrukar syre och förhindrar därmed att kopparkapslarna korroderar. De kan också producera ämnen som ökar korrosionen.

Subterranean microbes consume oxygen, and therefore prevent the copper canisters from corrosion. They can also produce substances that increase the corrosion.

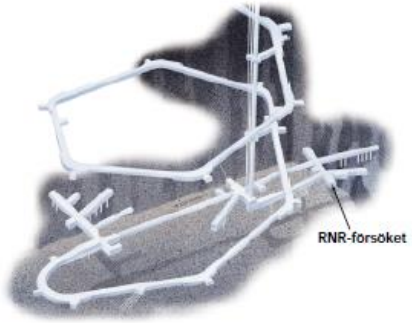


RNR-försöket – Radionuclide Retention Experiment

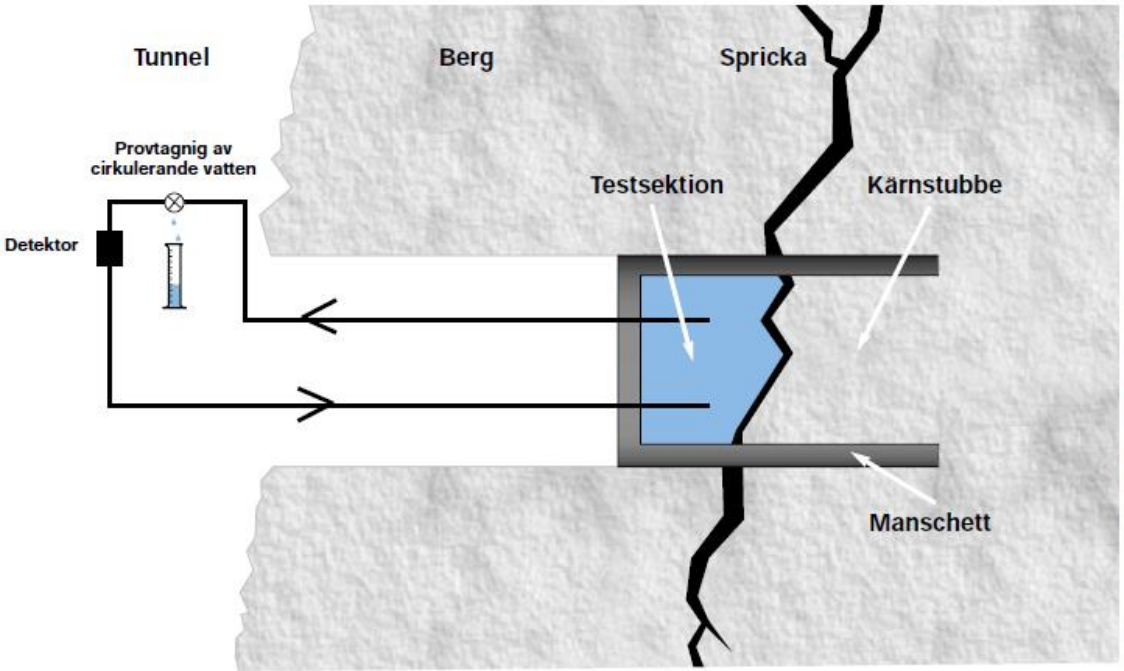


En utbytbar cell i en specialbyggd sond gör det möjligt att göra experiment om hur radioaktiva ämnen rör sig.

An exchangeable cell in a specially built probe makes it possible to conduct experiments on how radionuclides move.

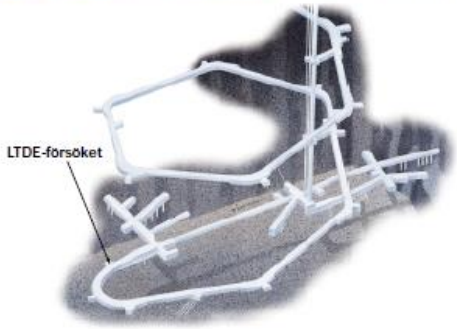


LTDE-försöket – Long Term Diffusion Experiment

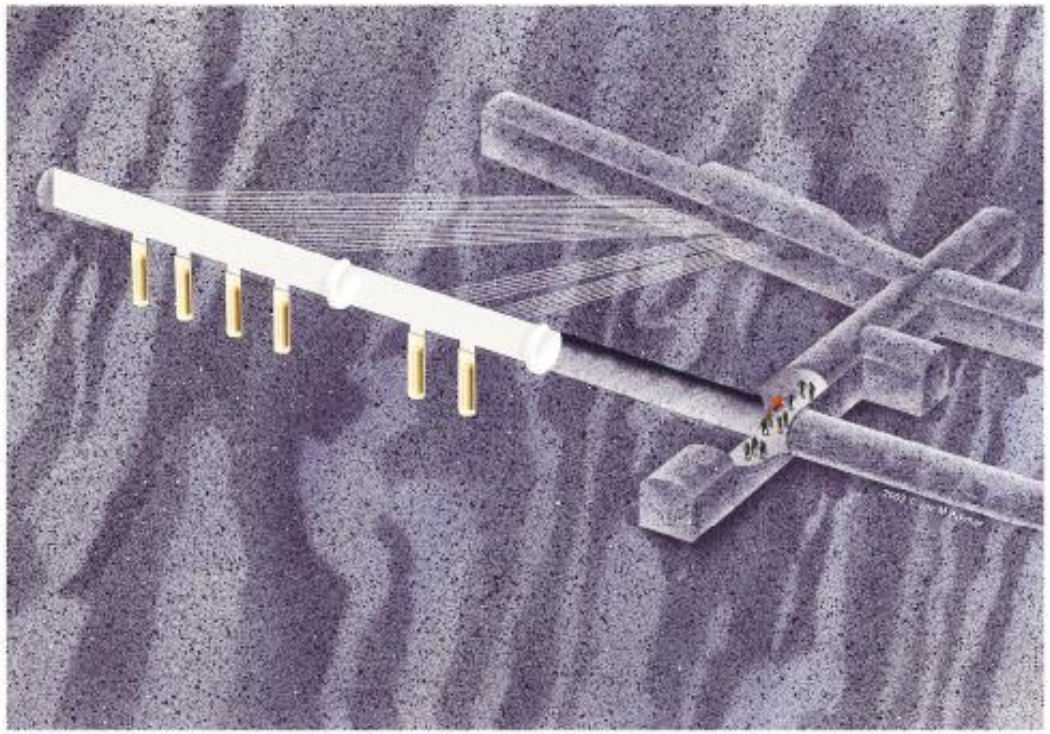


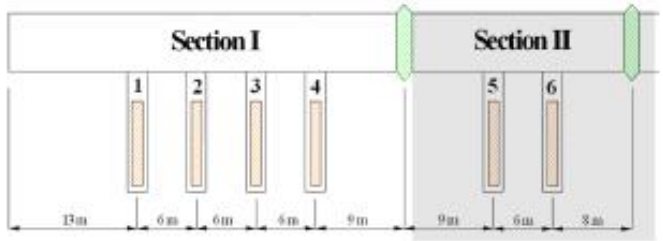
I LTDE-försöket undersöker vi under realistiska förhållanden i vilken utsträckning olika radioaktiva ämnen tar sig in i bergsmatrisen.

In the LTDE experiment we investigate to what extent different radionuclides migrate into the rock matrix.



Prototypförvaret – Prototype Repository





Prototypförvarets inre sektion(I) installerades 2001 och den yttre sektionen(II) 2003. Den yttre sektionen öppnades under 2011 och de två kapslarna återtogs. Den inre inre sektionen med fyra kapslar är fortfarande i drift.

The inner section of the prototype repository (I) was installed 2001 and the outer section (II) was installed 2003. The outer section was excavated during 2011, and the two canisters were retrieved. The inner section with four canisters is in continued operation.

Canister Retrieival Test (CRT)

Three stages:

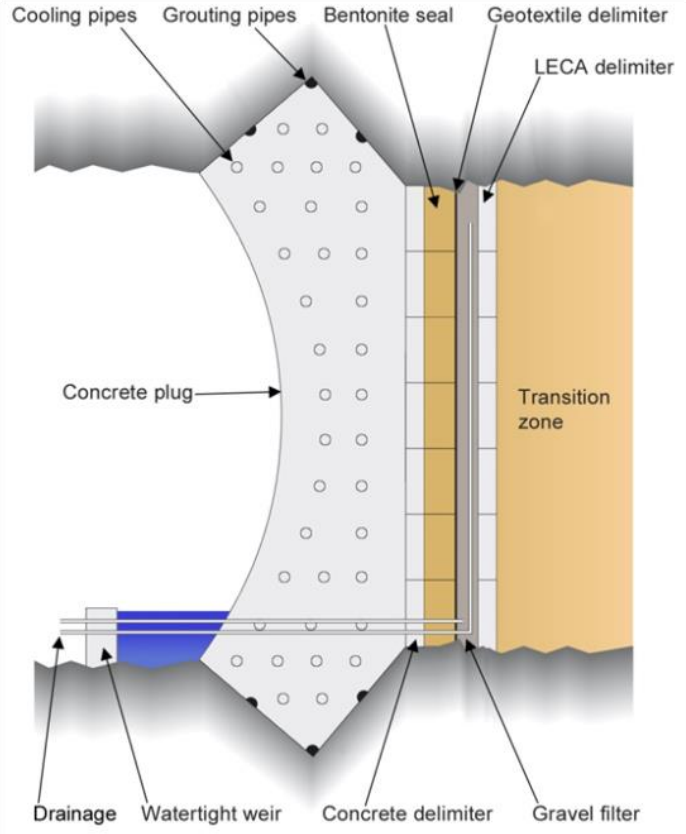
1. Boring of deposition holes and installation of instrumented bentonite blocks and canisters with heaters. **2000**
2. Saturation of the bentonite and evolution of the thermal regime with measurement of thermal, hydraulic and mechanical processes. **2000-2006**
3. of freeing the canister from the bentonite and retrieving it. **2006**

Mechanical rock excavation methods

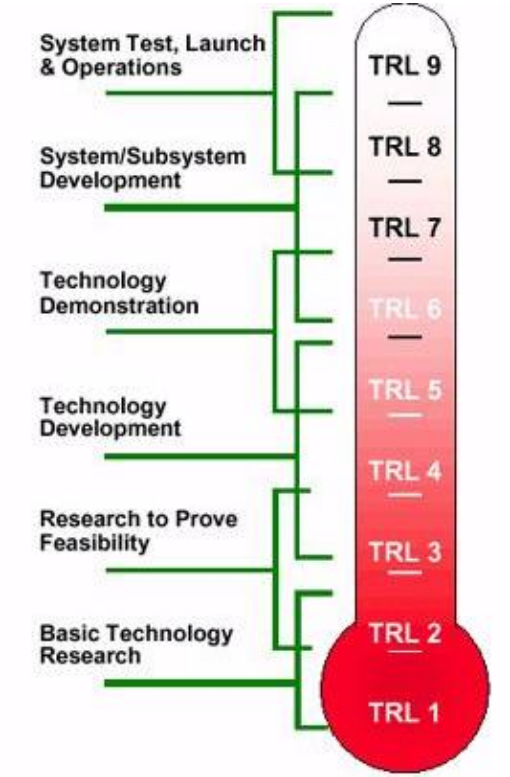
- Levelling of a tunnel floor by wire sawing

Domplu (Deposition tunnel dome plug)

- Demonstration of the construction method and testing of water tightness of the plug system at high pressure (4 MPa)
- Check of gas tightness and strength testing at very high pressure



The activities at Äspö HRL lead to increased technological maturity in the geological disposal program and provide flawless proof to the safety assessment and the license application for the repository.



The term "Technology Readiness Levels" was originally created by NASA in 1974 and was formally defined in 1989.

TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space).
TRL 8 – system complete and qualified
TRL 7 – system prototype demonstration in operational environment
TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 4 – technology validated in lab
TRL 3 – experimental proof of concept
TRL 2 – technology concept formulated
TRL 1 – basic principles observed

The TRL scale is also used extensively in Swedish and European research programs, often requiring the TRL level to be achieved in the projects

Thanks you for the attention!