Geological site selction process for the high-level nuclear waste repository in Finland

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Nuclear power plants in Finland (1977-)

- Fortum Power and Heat: 2 reactors at Hästholmen, Loviisa, 976 MW
- Teollisuuden Voima Oy (TVO): 2 reactors at Olkiluoto, Eurajoki, 1720 MW
- Olkiluoto 3 under construction (will be operational in 2012), 1600 MW

- The four power plant units generate 25,4% of the electricity consumed in Finland (2008)

- Positive Decission-in-Principle for two new reactors (2010)
  - TVO (Olkiluoto-4, 1000-1800 MW)
  - Fennovoima (1500-2500 MW)

Nuclear waste

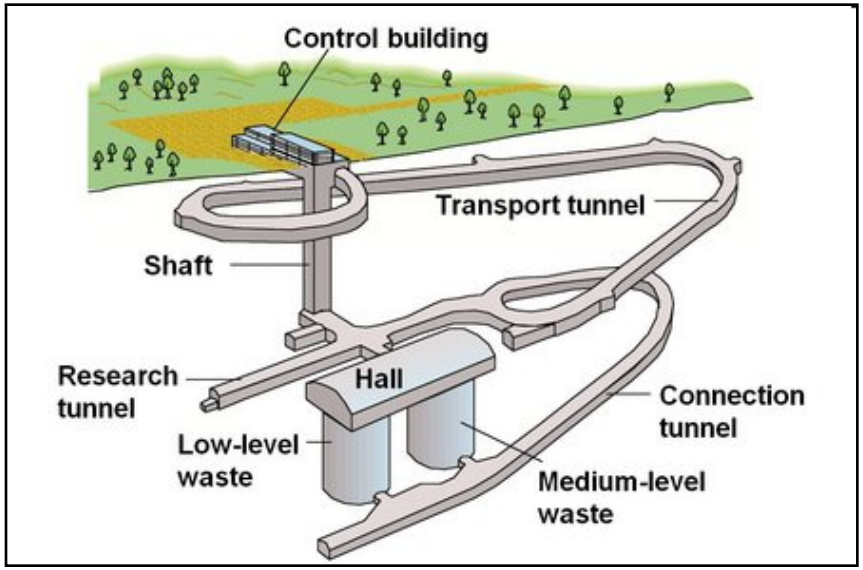
- 70 tons of spent fuel/year
- 200-400m^3 of low and intermediate level operating waste/year (2008)

- Operating waste is deposited in reactor waste (RW) repositories at the plant sites
  - Olkiluoto since1992
  - Loviisa since1997

- In total 5500 tU spent fuel for final disposal assuming that 5 units are in operation for 60 years

- Decission-in-principle to expand the Olkiluoto repository (2010) for 9 000 tU (OL-4)

- Decommissioning waste (some power plant structures)



RW repository, Posiva Oy

Nuclear waste management principles

- *Any nuclear waste generated in Finland shall be disposed in Finland (Nuclear Energy Act, 6a §).*
- The nuclear power companies are responsible for practical preparations, research and the final disposal of nuclear waste
- The Finnish authorities are responsible for the principles governing nuclear waste management, safety criteria and for ensuring that legislation is complied with
- Funds for nuclear waste management are collected in advance in the price of nuclear electricity

Final disposal of spent nuclear fuel - Milestones

- Proposal for Finnish approach to manage spent nuclear fuel
  - Final disposal in a deep bedrock repository (about 500 m)
  - Stable Archean/Proterozoic bedrock (1250 Ma - 3200 Ma)
  - Low seismic activity, no active volcanoes, metamorphic, hard rocks with low porosity

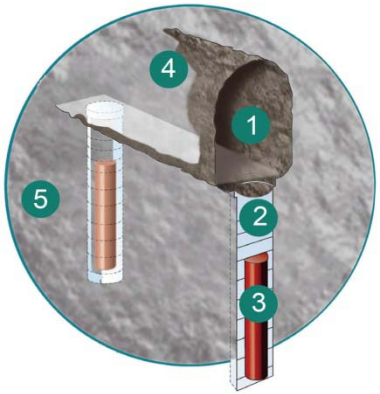
- Positive statement of the suitability of the Finnish bedrock based on wide archive of data, 1978-1982

- Decision-in-principle regarding the aims and the time table for the selection of the final disposal site (the Finnish Governement, 1983)
  - Stepwise programme of bedrock investigations
  - Final disposal will start at 2020

→ ***Politically, economically and scientifically transparent programme has been a success***

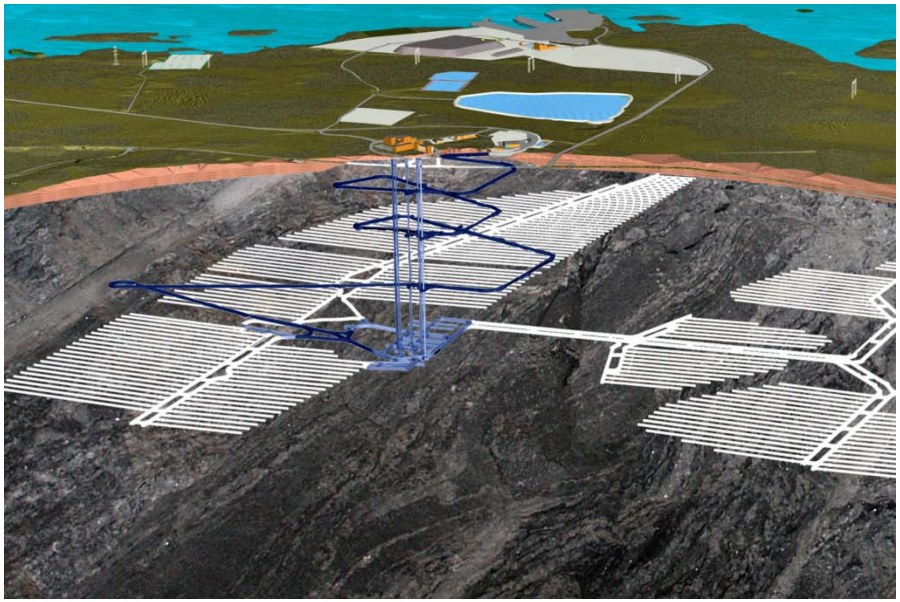
KBS-3 Concept

- Developed by the Swedish Nuclear Fuel and Waste Management Co. (SKB)
- Isolation of the waste from organic nature and humans → final disposal in deep bedrock repository
- Use of multiple, independently performing release barriers → deficiency of a single barrier does not endanger the isolation



1. Disposal tunnel
2. Bentonite
3. Disposal canister
4. Tunnel backfill
5. Host rock

- Release barriers
  - physical state of the fuel
  - disposal canister
  - bentonite buffer
  - backfilling of the tunnels
  - **surrounding rock and groundwater**



Responsible organizations (1977-)

- Power companies: TVO and IVO
- 1978 Nuclear Waste Commission of Finnish Power Companies
  - Coordination of R&D
- 1995 Posiva Oy (TVO and Fortum Power and Heat)

- Ministry of trade and industry/Ministry of employment and the economy
- Radiation and Nuclear Safety Authority (STUK)

- Research institutes, universities, consulting companies…..

Geological suitability criteria

- International OECD/NEA guidelines (1977) for nuclear waste disposal and site selection adapted to Finnish conditions

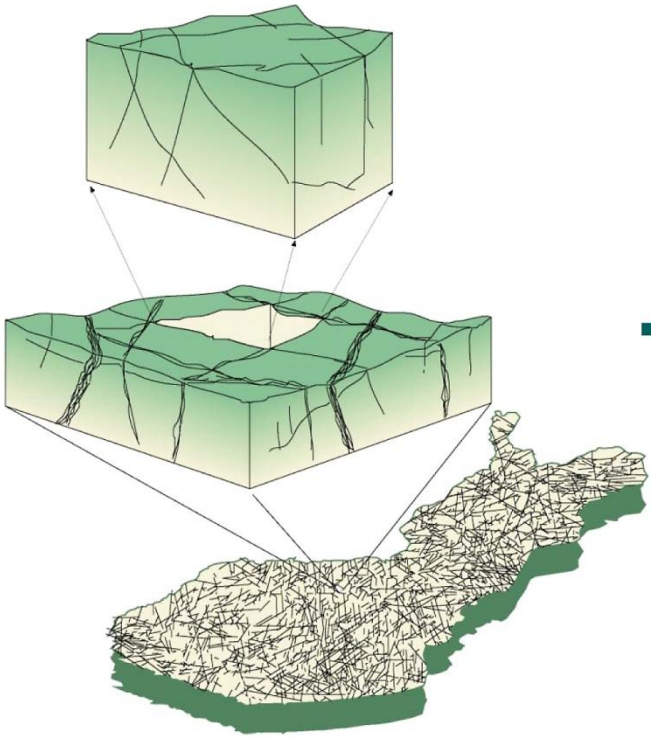
  - Geological unit of sufficient size to host a deep repository
  - Stability of bedrock in terms of tectonics and underground facility
  - Sparcely fractured bedrock unit avoiding faults and fractured zones
  - Stable groundwater conditions in terms of chemistry and flow
  - Retardation capacity for radionuclides
  - Smooth topography (low hydraulic gradient, homogeneous stress field)
  - The bedrock should compose of common rock types not interesting for raw material exploration

Geological background data

- Geological and geophysical information covering the whole country
  - Bedrock geology
  - Quaternary geology
  - Geophysical airborne high- and low-altitude maps
  - Geochemical maps (lithogeochemistry, soil, surface water)
  - Satellite images, aerial photos, topographic maps

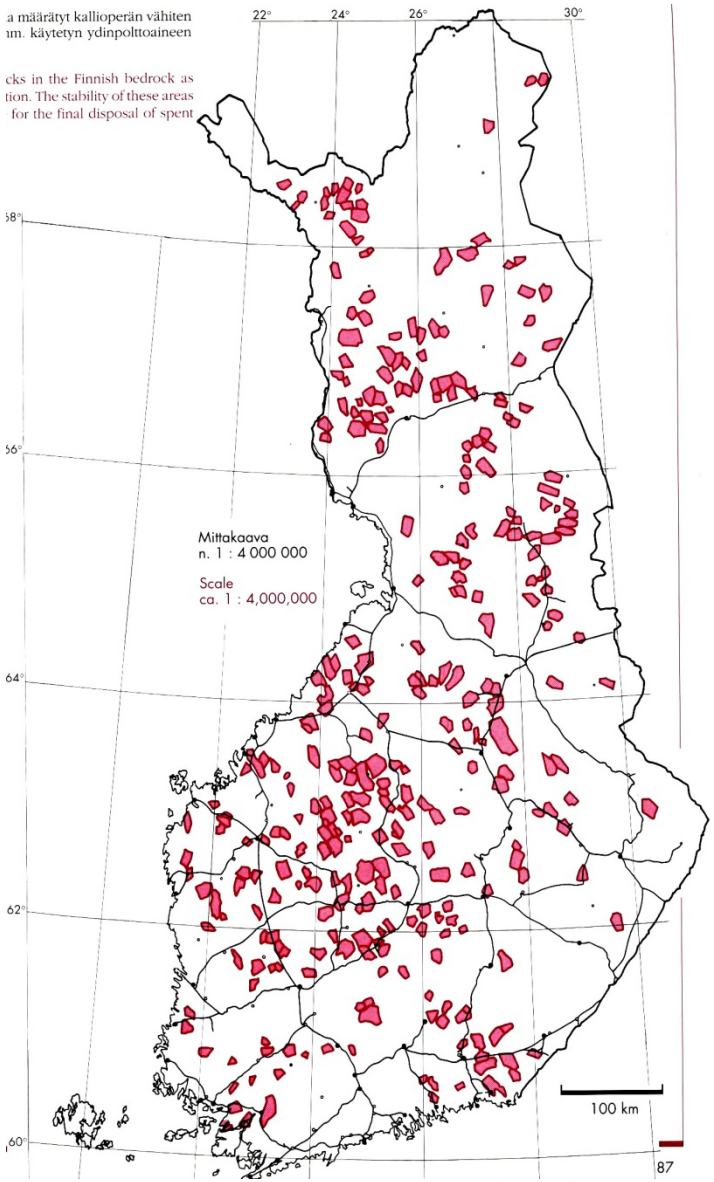
- Supplementary investigations *e.g.*
  - Lineaments (brittle deformation structures)
  - Geochmistry and flow of deep groundwaters

Principles of site selection



- A multiphase procedure where the number of sites decreases and the level of information increases
  - → Data collection down to repository level
  - → Data collection also for the needs of long-term performance and safety assessments
- Geological screening of the whole country
  - → Less broken bedrock blocks surrounded by fracture zones and large enough for a disposal site
- Evaluation of environmental factors (*e.g.* population density, preservation areas, groundwater basins, land use plans, land ownership, transport)

Site selection process *(Posiva Oy)*



GENERAL GEOLOGICAL STUDIES — 1980 - 1982

- GENERAL APPLICABILITY OF FINNISH BEDROCK FOR FINAL DISPOSAL OF SPENT FUEL

SITE IDENTIFICATION SURVEY

REGIONAL STUDY — 1983

- SATELLITE PHOTO INTERPRETATION
- GEOLOGICAL AND GEOPHYSICAL MAPS
- IDENTIFICATION OF BEDROCK BLOCKS (100-200 KM2)

327 REGIONAL BLOCKS

EVALUATION OF ENVIRONMENTAL FACTORS

- POPULATION DENSITY AND TRANSPORT CONNECTIONS
- PRESERVATION AREAS AND GROUNDWATER BASINS
- LAND USE PLANS

162 REGIONAL BLOCKS — 1984

GEOLOGICAL STUDIES OF REGIONAL BLOCKS

- SATELLITE PHOTO INTERPRETATION
- FIELD CHECKING

61 REGIONAL BLOCKS

IDENTIFICATION OF INVESTIGATION AREAS (5-10 KM2)

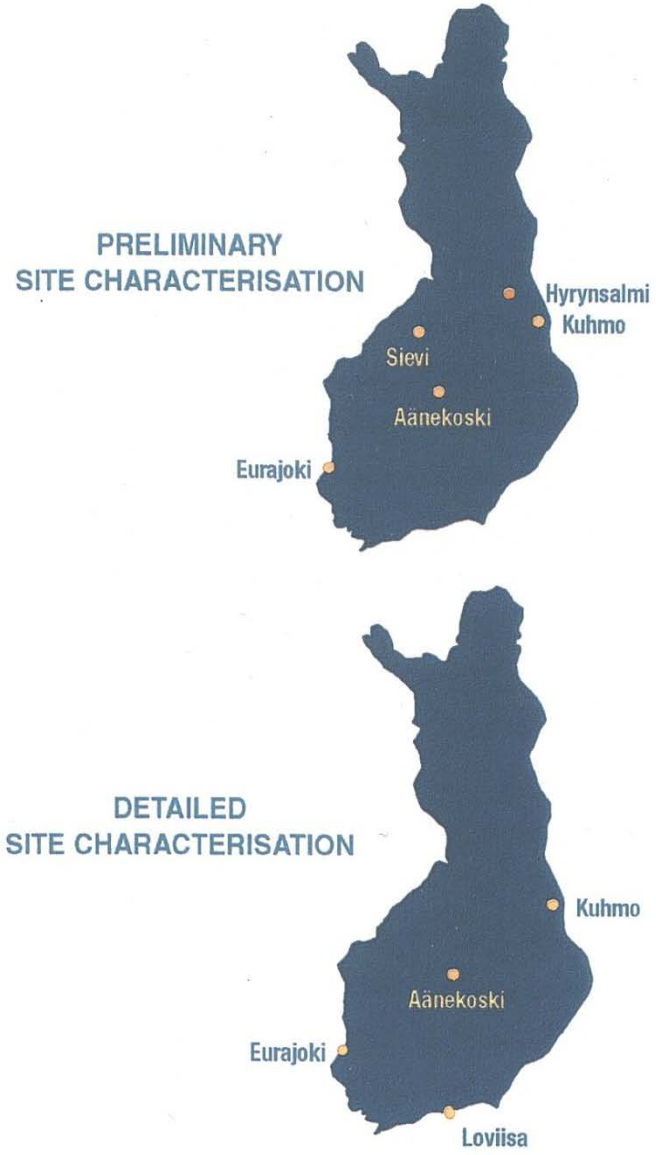
- STEREO INTERPRETATION OF AERIAL PHOTOS
- INTERPRETATION OF TOPOGRAPHIC MAPS
- CLASSIFICATION OF FRACTURE ZONES

134 INVESTIGATION AREAS — 1985

GEOLOGICAL CLASSIFICATION	ENVIRONMENTAL FACTORS
• FIELD CHECKING	• POPULATION DENSITY
• COMPILATION AND EVALUATION OF DATA	• LAND OWNERSHIP
	• TRANSPORT

101 POTENTIAL INVESTIGATION AREAS

Site selection process (cont.)



EVALUATION BY AUTHORITIES — 1986

85 POTENTIAL INVESTIGATION AREAS — 1986

SELECTION OF SITES FOR PRELIMINARY CHARACTERISATION

- GEOLOGICAL VARIATION (MAIN FORMATION UNITS)
- ENVIRONMENTAL FACTORS
- DISCUSSIONS WITH COMMUNITIES

PRELIMINARY SITE CHARACTERISATION — 1987 - 1992

- FIELD INVESTIGATIONS AT FIVE SITES
- DEVELOPMENT OF GEOLOGICAL MODELS
- EVALUATION OF HYDROGEOLOGY AND HYDROGEOCHEMISTRY

SELECTION OF SITES FOR DETAILED CHARACTERISATION — 1992

- AMENABLE FOR FURTHER SITE INVESTIGATIONS
- AMOUNT OF UNCERTAINTY
- POTENTIAL AND FLEXIBILITY FOR REPOSITOR DESIGN

REVIEW BY AUTHORITIES — 1993

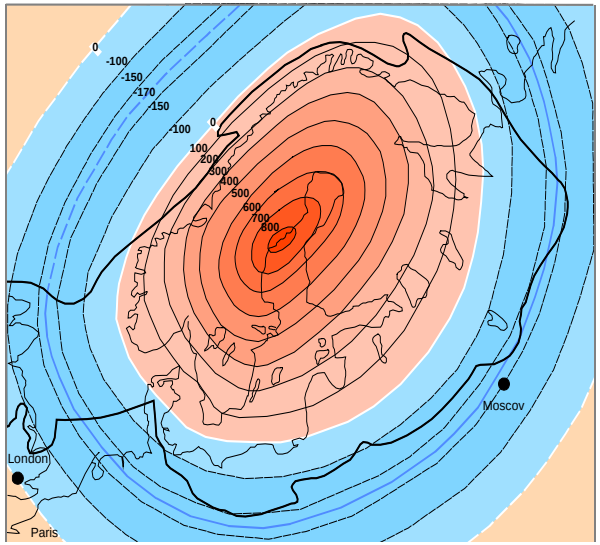
DETAILED SITE CHARACTERISATION — 1993 - 2000

- BASELINE STUDIES ON HYDROLOGY AND HYDROGEOCHEMISTRY
- COMPLEMENTARY FIELD INVESTIGATIONS AT THREE SITES
- FEASIBILITY STUDY AND CHARACTERISATION OF HÄSTHOLMEN IN LOVIISA
- ASSESSING GOUNDWATER FLOW AND HYDROGEOCHEMISTRY
- EVALUATION OF ROCK MECHANICAL PROPERTIES
- EVALUATION OF CONSTRUCTABILITY

Site selection process (cont.)

- 2000 Posiva proposed Olkiluoto as the site for repository
- Government made a decission-in-principle in favour for the selection and the Parliament ratified the decission in 2001
- Since that investigations have been focused to Olkiluoto
- The construction of an underground rock characterization facility (ONKALO) begun at Olkiluoto in 2004

Long-term safety of the geological disposal concept



- The safety of the repository must be assessed at least for 100 000 years
- Research to understand long-term processes and to improve the general acceptance and the safety of the concept
  - Studies on ice age scenarios
    - Hydrogeological and hydrogeochemical stability of deep groundwaters
    - Bedrock stability
  - Studies on natural analogues for:
    - Transport of radionuclides
    - Copper canister corrosion
    - Permafrost (Arctic Canada)
    - Melt waters under glacial conditions (Greenland)

International co-operation

- Safety of the nuclear waste disposal is an inter-diciplinary (geosciences, radiochemistry, material sciences etc.) and a global issue → most research projects are co-operative

- National and international networking:
  - Nuclear Waste Management Companies:
    - Posiva (Finland), SKB (Sweden), ENRESA (Spain), ANDRA (France), NDA (UK), NWMO (Canada)
  - Numerous research organizations and universities in:
    - Finland, Sweden, Denmark, Belgium, UK, France, Spain, Canada, USA etc.


Thank you!