# Crystalline Rock Repository Concepts and the Role of Engineered an Natural Barriers

Edward S. Patera

Los Alamos National Laboratory

OECD Nations Considering Crystalline Rock as a Host Medium for Geological Disposal of Radioactive Waste.

- CANADA
- FINLAND
- FRANCE *
- JAPAN*
- SPAIN*
- SWEDEN
- SWITZERLAND*

*also considering other geological formations, clay, salt.

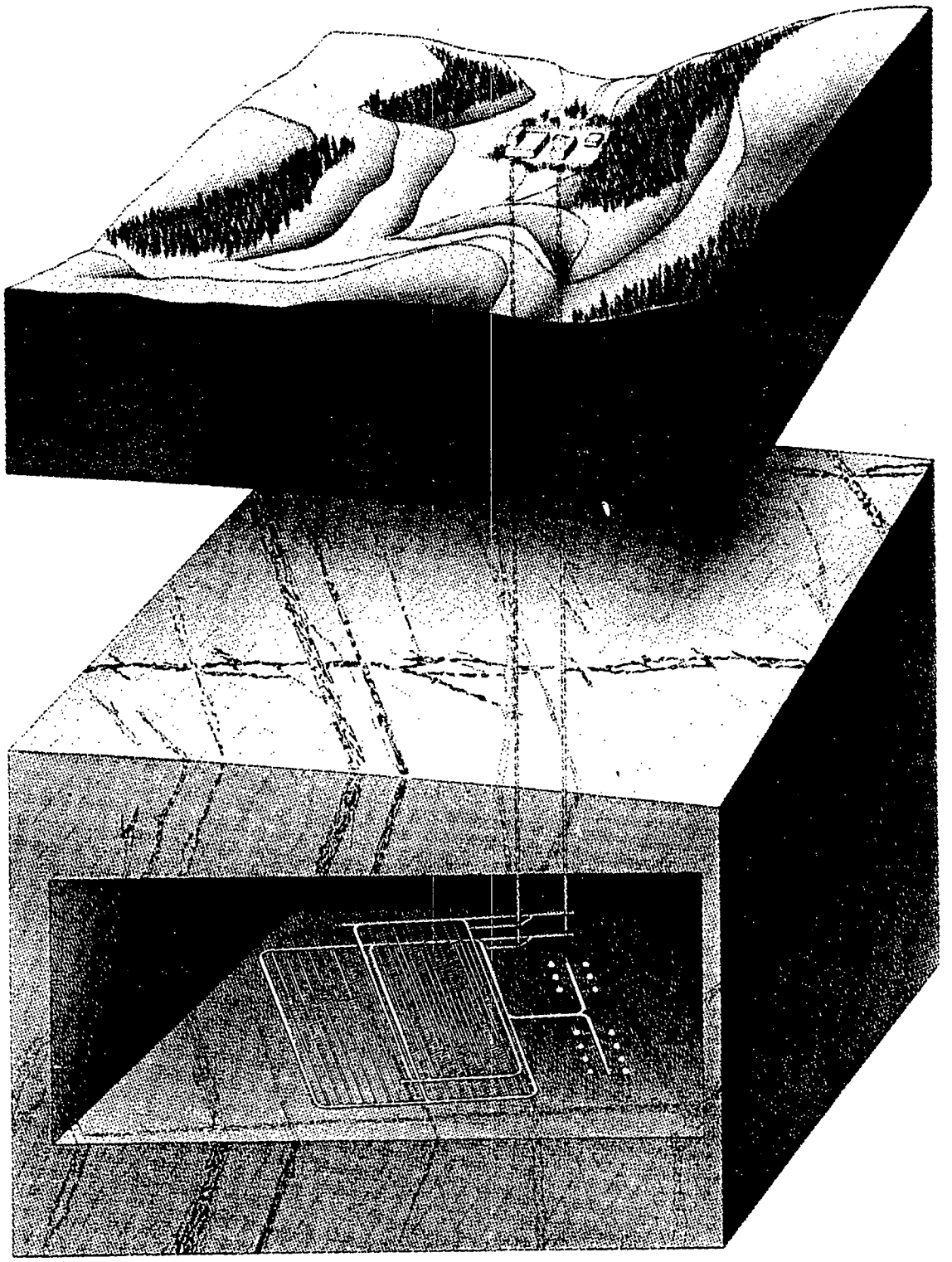
# The Properties of Crystalline Rock as a Host Medium for Disposal

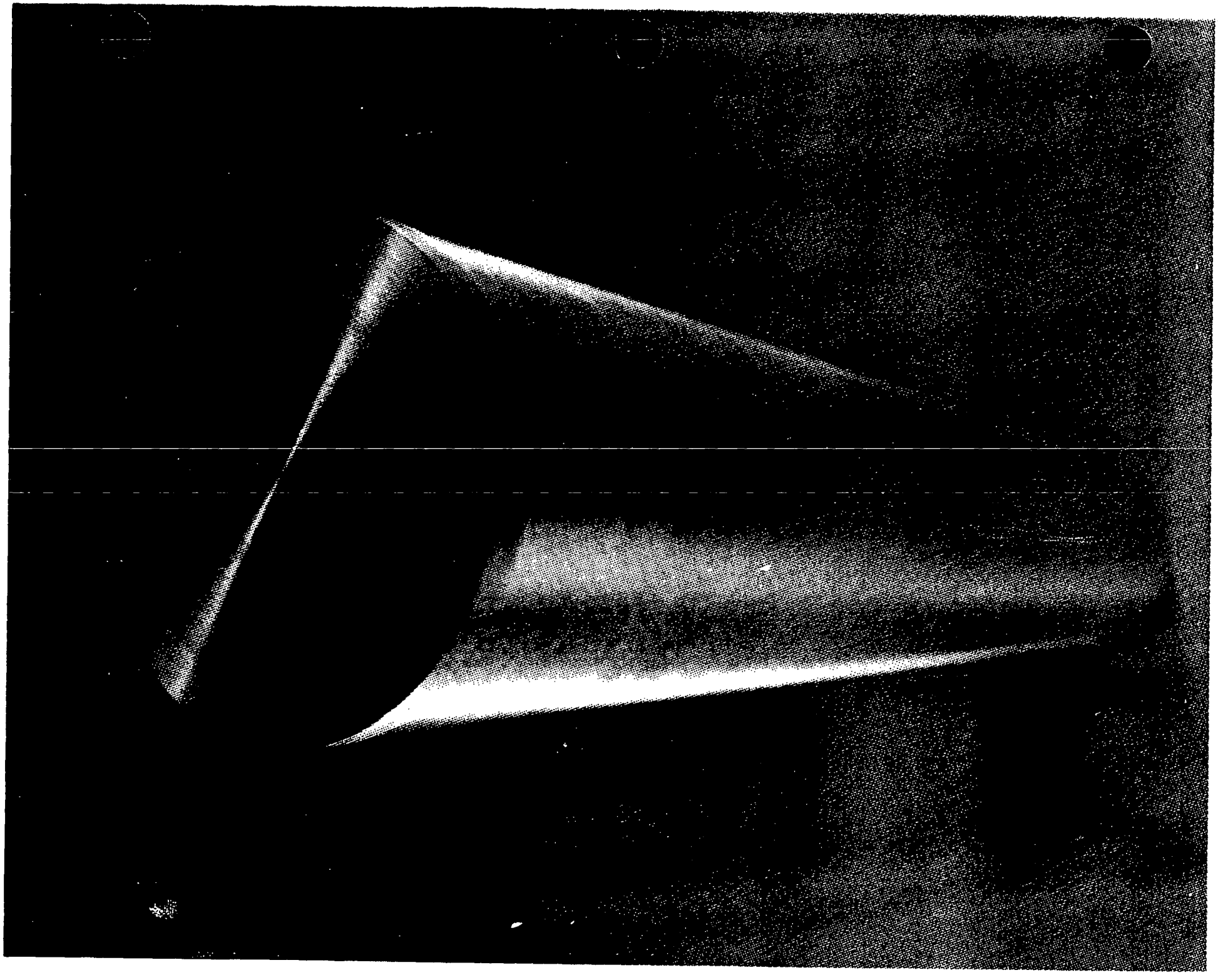
ADVANTAGES:

- Hydrology
  - low porosity
  - low hydraulic conductivity
- Chemistry
  - reducing conditions
  - sorptive potential of mineralogy
- Geochemical
  - solid competent rock
  - easily mined
  - not limited to 2-D design
- Human Action- can be sited in area of low resource potential

DISADVANTAGE:

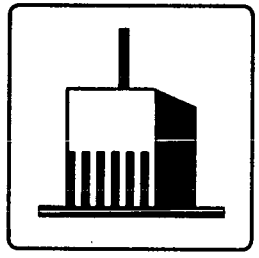
- The occurrence of large scale fractures that can act as conduits for radionuclide migration to the accessible environment.





**The law says that whoever operates nuclear power plants is obligated to dispose of the waste in a safe manner.**

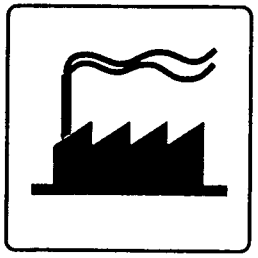
# The Swedish system



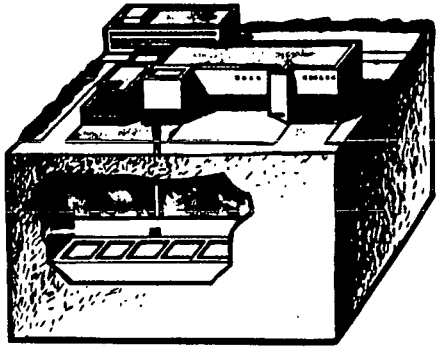
Nuclear power stations

*Spent fuel*

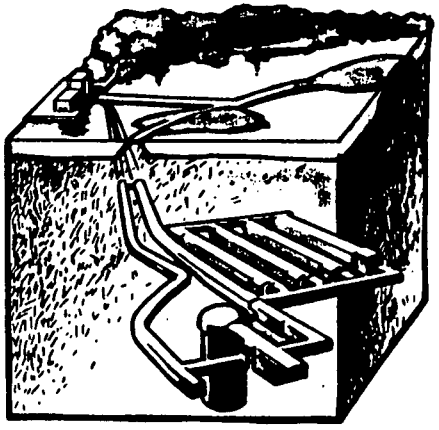
*Operational waste*



Medical care
Industry
Research



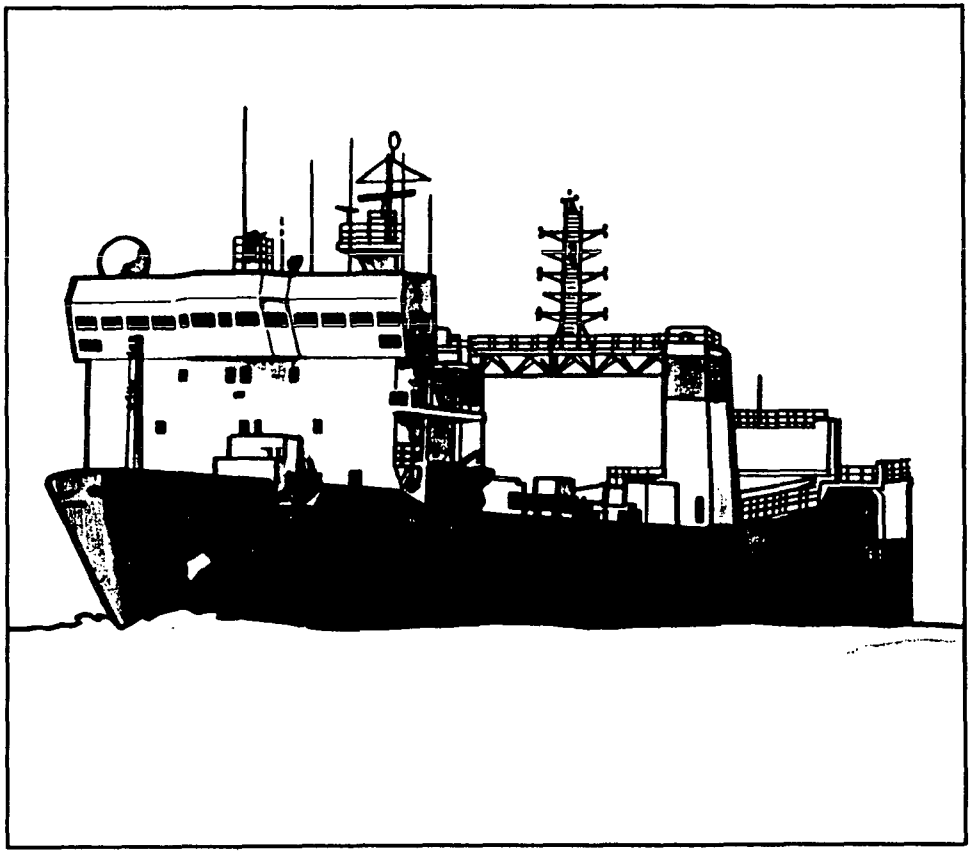
Central interim storage facility for spent nuclear fuel (CLAB). Start of operation 1985.



Final repository for radioactive operational waste (SFR). Start of operation 1988.

Deep geological repository for spent nuclear fuel. First stage of deposition 2008 at the earliest.

# Transportation



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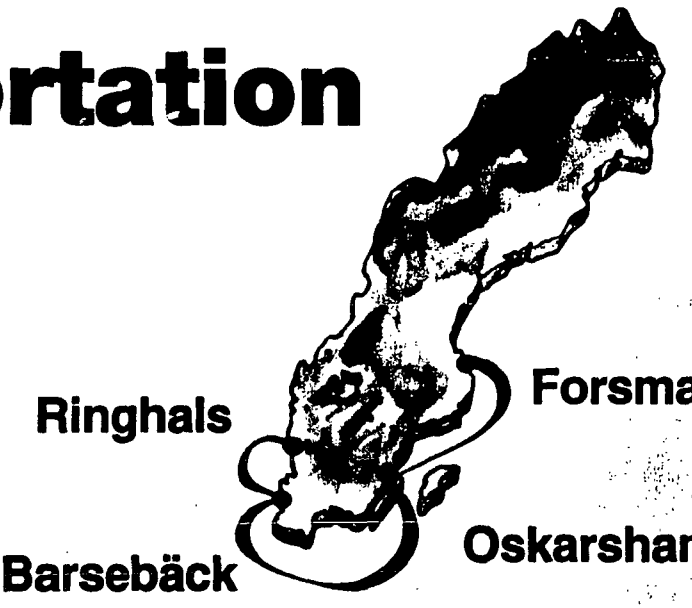
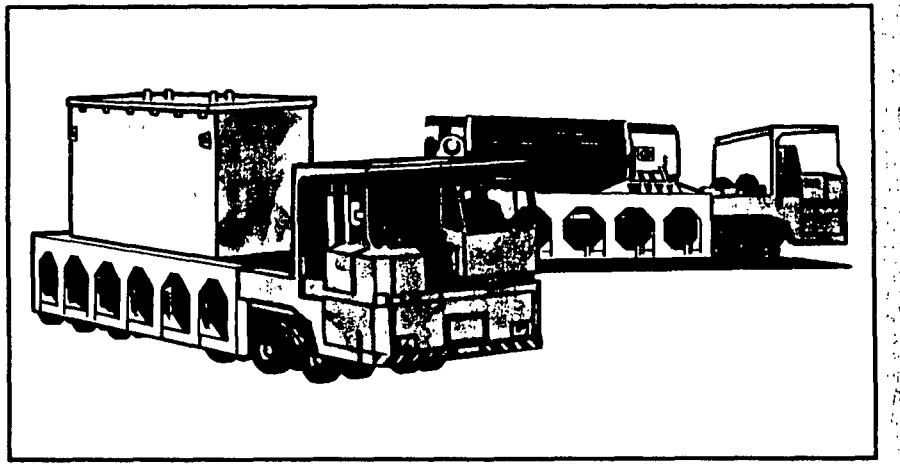
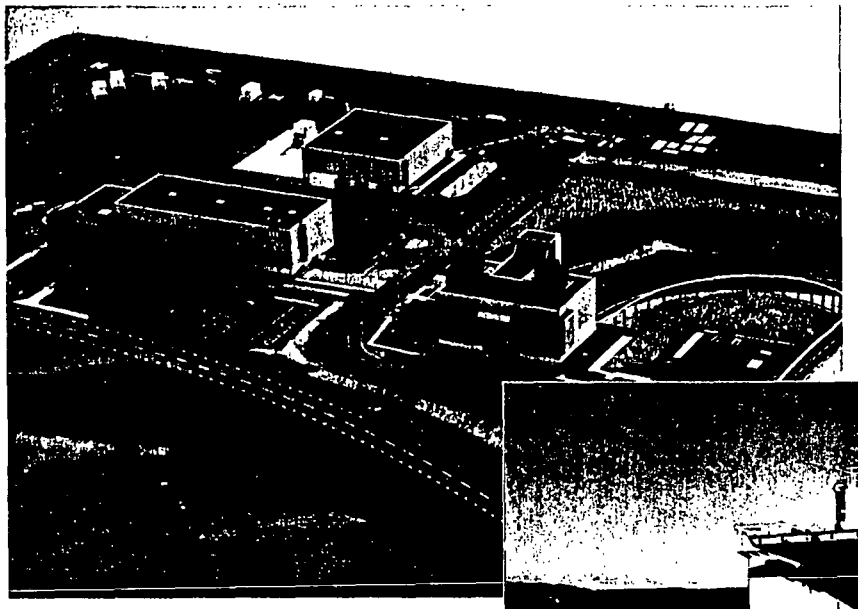
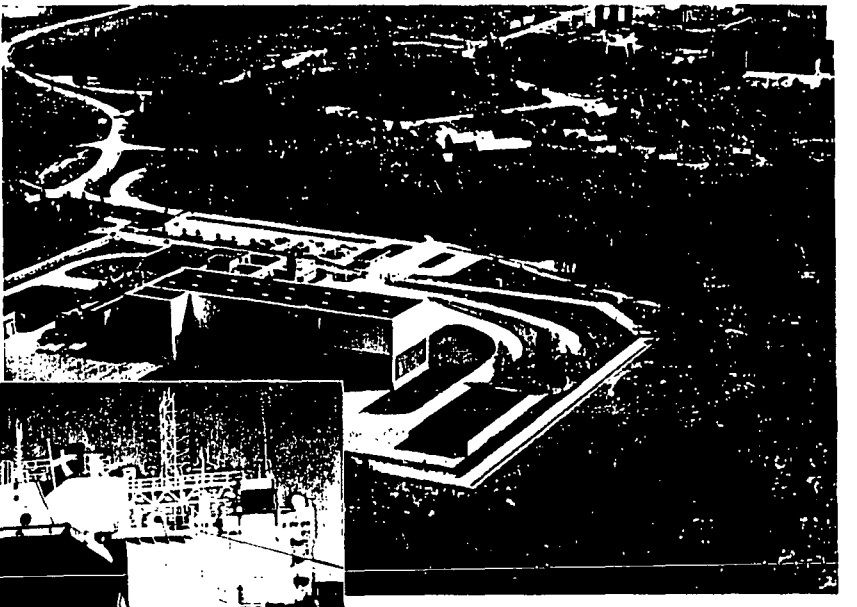


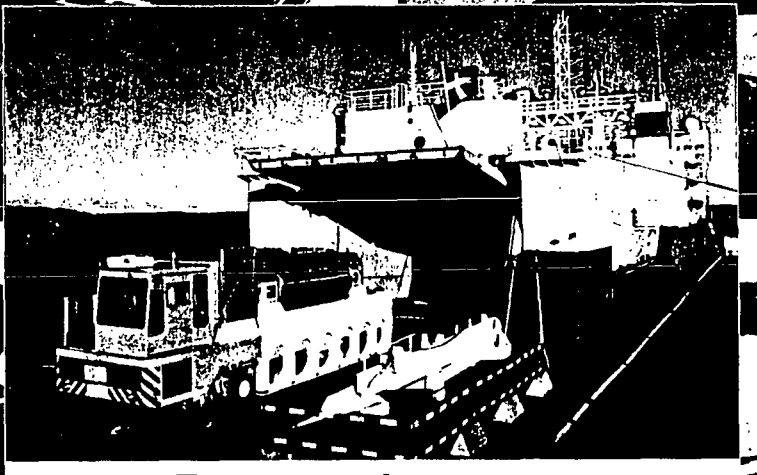
Terminal vehicles with transport containers



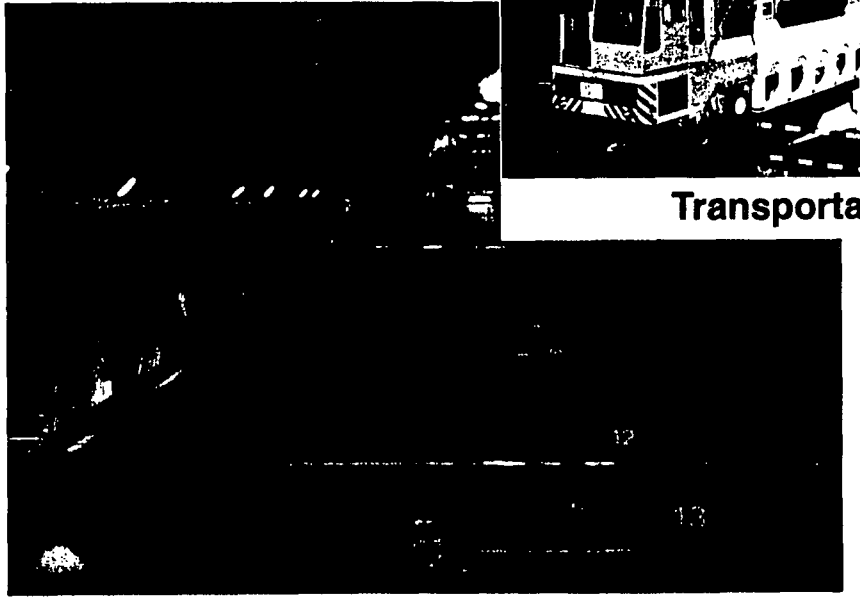
SFR



CLAB



Transportation system



Rock cavern in SFR

Storage pools in CLAB

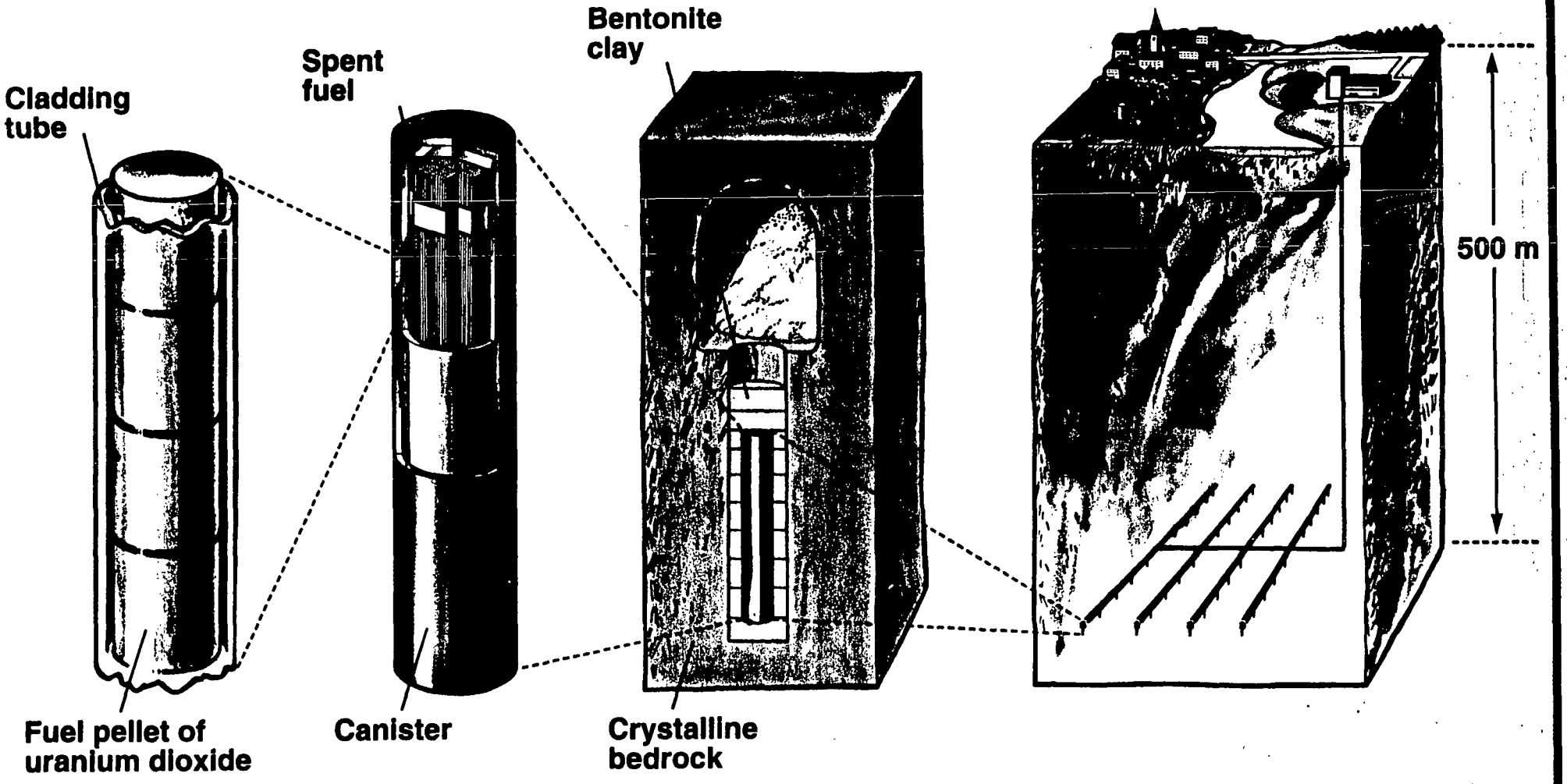
# How will the waste be disposed of?

**Isolation from man by means of:**

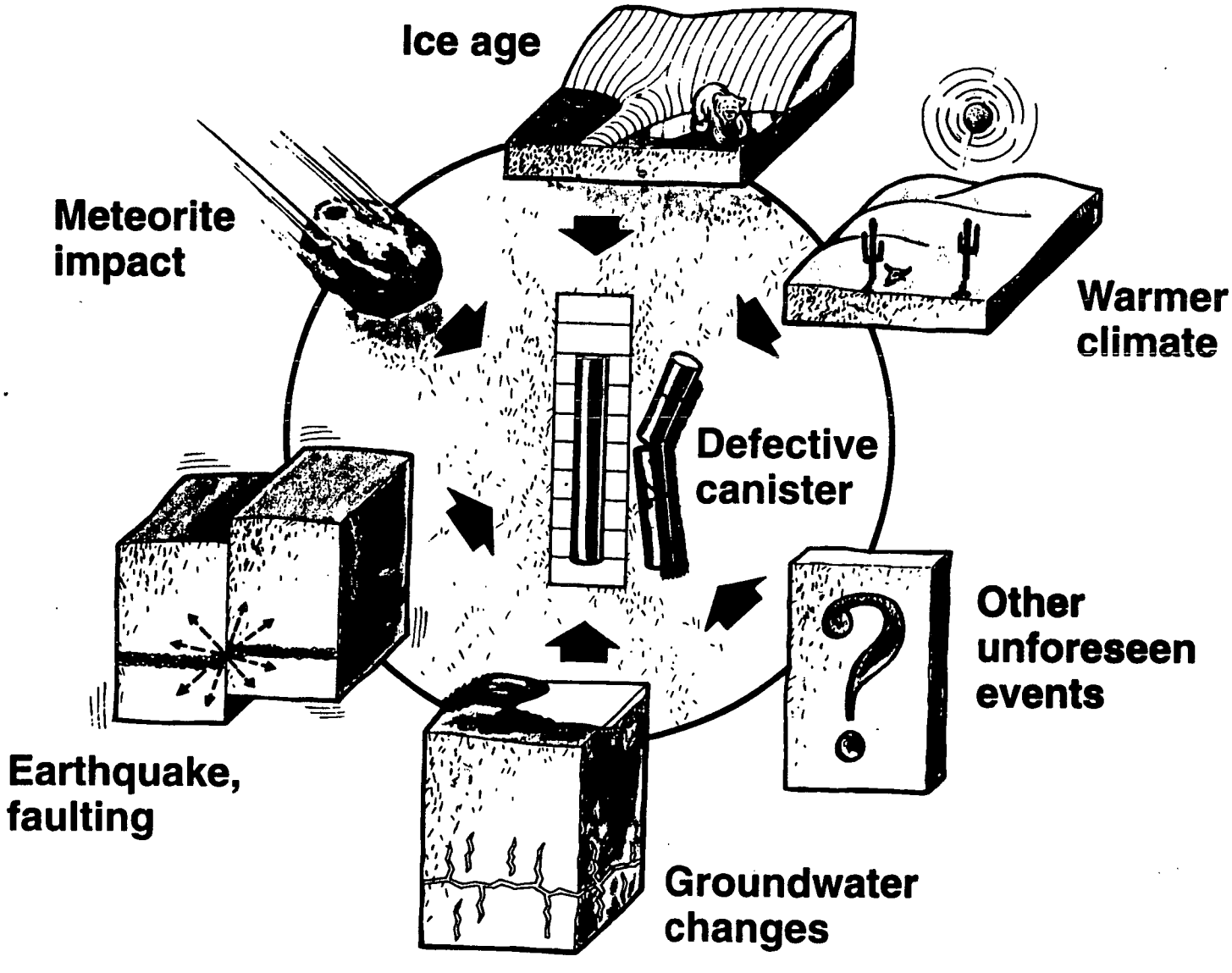
| | |
|---|---|
| **Stable host environment:** | **Crystalline bedrock** |
| **Stable barrier materials:** | **Naturally occurring materials such as copper and clay** |
| **Stable ambient conditions:** | **Little impact on temperature and chemical processes** |
| [illegible] | [illegible] |

**Furthermore, the waste is handled and disposed of in solid form.**

# Deep repository for spent nuclear fuel



# Safety assessment – scenarios



# The Swedish KBS-III System

## Final Repository System

Principle Functions:

- To contain radinuclides for a long period of time (first phase).
- After the first phase, the system will dilute radionuclides by slow release and dispersal through the geosphere.

# The Swedish KBS-III System

## Canister System

Principle Function:

- Contain spent fuel for a long period of time (> 1 Million Years) and thus prevents release of radionuclides into the groundwater.

# The Swedish KBS-III System

## Barrier System

Principle Functions:

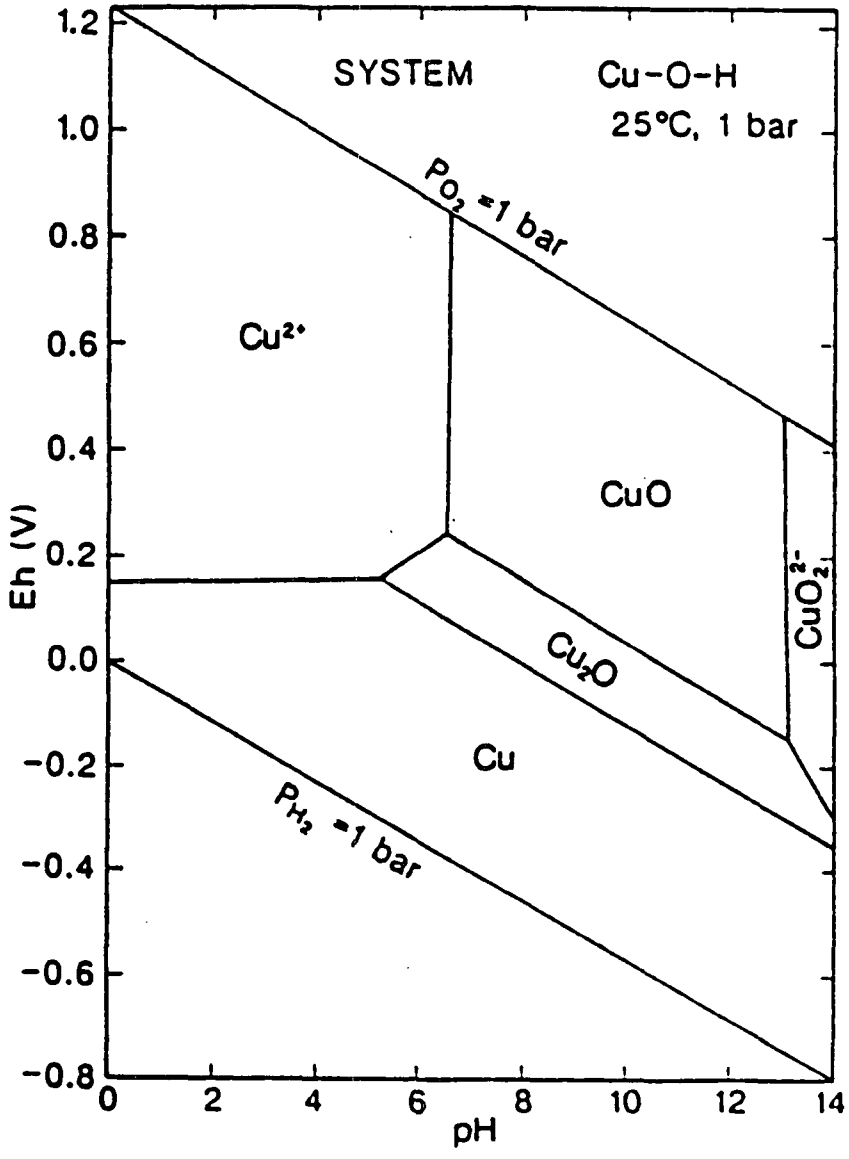
- Provide mechanical and chemical zone protection around the canister.
- Limit the inward transport of corrosive substances to the canister.
- In the event of a canister failure, limit the outward migration of leached radionuclides.

# The Swedish KBS-III System

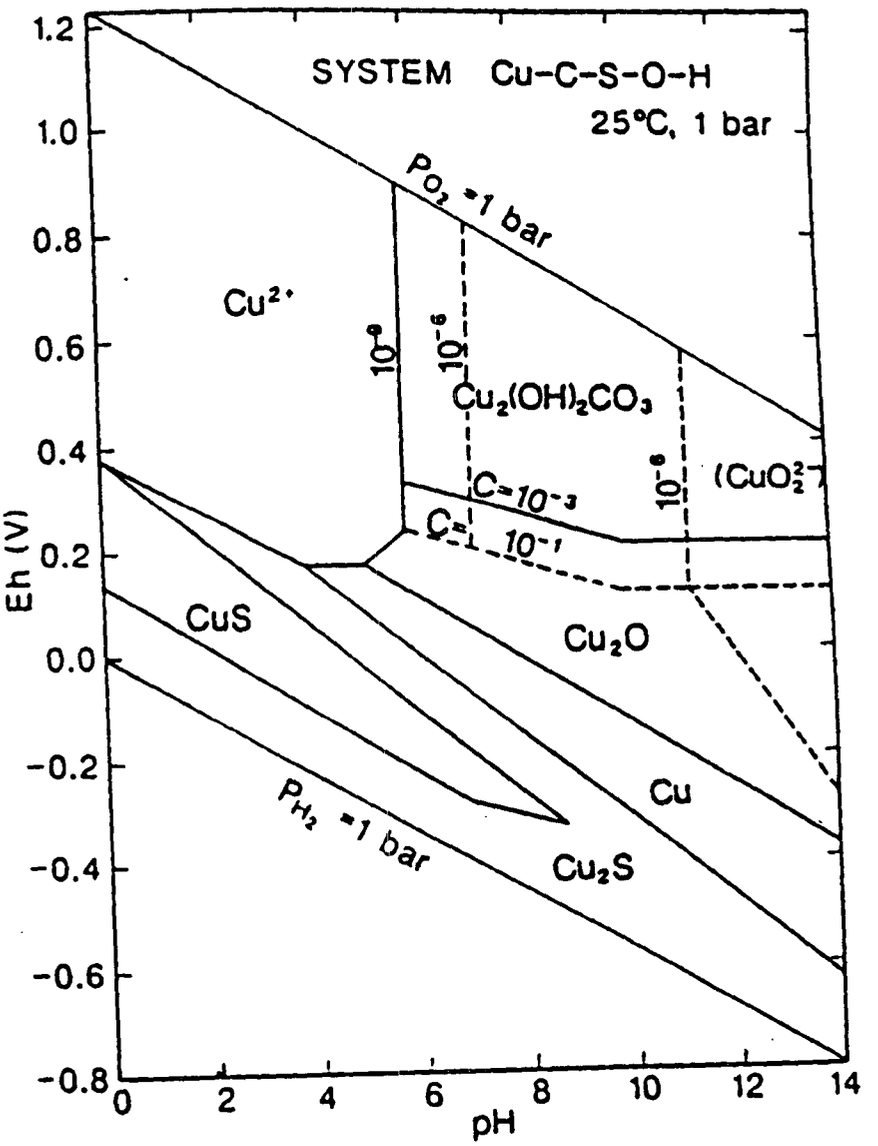
## The Geological Barrier

Essential Properties:

- Low hydraulic conductivity.
- Sorptive properties of the fracture surfaces.
- Diffusion of dissolved radionuclides into microfissures within the rock.




*Potential pH diagram for the copper/water system*

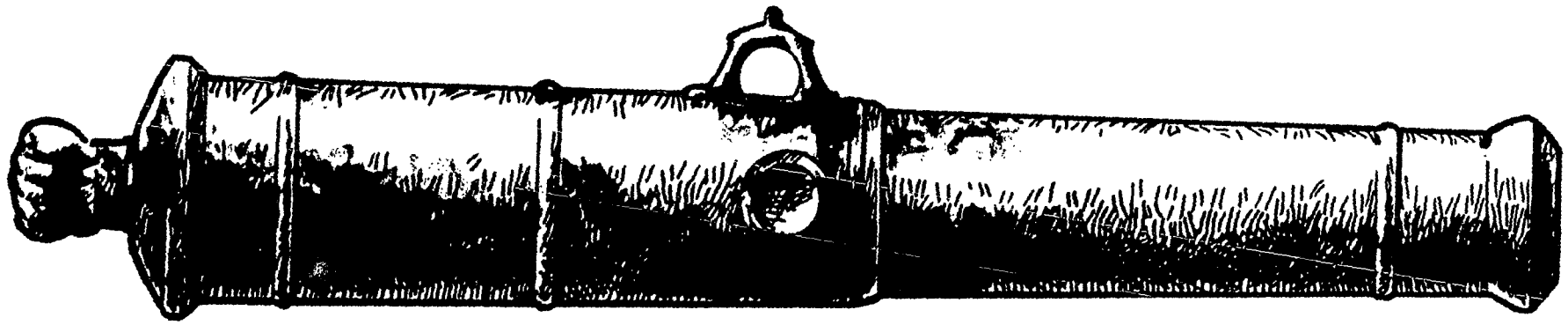



*Potential pH diagram for the copper/sulphur/carbon/water system*

# Method to Prove the Corrosive Resistance of a Copper Canister

- Laboratory corrosion tests (a few years).
- Measurements of corrosion from modern applications of copper (~ 100 years).
- Measurements of corrosion on historic and prehistoric copper based artifacts (100 - 5000 years).
- Studies of naturally occuring native copper ore deposits (millions of years).

# The cannon from the "Kronan"



**A "copper canister" embedded in mud since the 17th century verifies researchers calculations that copper corrodes only a few mm in 100,000 years.**

# CONCLUSIONS

- Long lived and robust engineered barriers, especially a copper canister, can provide a high degree of confidence that radionuclides can be contained within a geological disposal system.

- This high degree of confidence can be shared by scientist, engineers, politicians and the public.

# BELGIUM

| | | |
|---|---|---|
| Waste form | - | Vitrified HLW from reprocessing. |
| Geological media | - | Clay. |
| Reference canister | - | Carbon steel overpack. |
| Buffer | - | None. |
| Status | - | Conducting research on disposal of HLW in clay, including an underground research facility at Mol. |

# CANADA

| | | |
|---|---|---|
| Waste Form | - | Spent CANDU nuclear fuel. |
| Geological media | - | Crystalline rock. |
| Reference canister | - | Titanium alloy or copper. |
| Buffer | - | Bentonite and sand mixture. |
| Status | - | AECL Whiteshell has finished the research and development on the concept of geological disposal of a crystalline repository system. An EIS is to be reviewed and recommendations made on the next step. |

# FINLAND

| | | |
|---|---|---|
| Waste form | - | BWR spent nuclear fuel. |
| Geological media | - | Crystalline rock. |
| Reference canister | - | Copper / steel composite. |
| Buffer | - | Highly compacted bentonite clay. |
| Status | - | TVO has selected five sites to characterize further. This was based on a voluntary process. TVO will select at least one site for detailed site characterization (exploratory shaft). |

# FRANCE

| | | |
|---|---|---|
| Waste form | - | HLW in boro-silicate glass from reprocessing. |
| Geological media | - | Clay and crystalline. |
| Reference canister | - | Vitrified HLW in stainless steel canister with carbon steel overpack. |
| Buffer | - | ? |
| Status | - | French law mandates research phases in three areas: 1) Geologic disposal with development of possibly two underground research facilities; 2) Transmutation and partition of radionuclides, and 3) long-term storage. Four areas have been selected, based on a volunteer process for possible development of underground research facilities, three in clay formations and one in crystalline. |

# GERMANY

| | | |
|---|---|---|
| Waste form | - | Vitrified HLW from reprocessing, possible direct disposal of spent fuel. |
| Geological media | - | Salt. |
| Reference Canister | - | Thick wall cast iron. |
| Buffer | - | None. |
| Status | - | Developing repository at Gorleben Salt Dome. However, much opposition and possible abandonment of this site as a political tradeoff. Germany has recently begun research on both crystalline and clay formations. |

# ITALY

Status - There is no program for disposing of high-level radioactive wastes in Italy.

# JAPAN

| | | |
|---|---|---|
| Waste form | - | Vitrified HLW for reprocessing. |
| Geological media | - | Considering many different types of Host rock. |
| Reference canister | - | Thick walled steel overpack. |
| Buffer | - | Highly compactable bentonite. |
| Status | - | Disposal program is in the research and development stage. The steering committee on High-Level Waste Project has been established to determine policies concerning implementing a geologic disposal program. |

# KOREA

Status - There is no program for the disposal of high-level nuclear waste. Away from reactor, interior storage will be utilized. Wet-type storage facility to be constructed by 1997.

# NETHERLANDS

Status - The Netherlands have abandoned research into the disposal of vitrified HLW in rock salt and will proceed with long-term storage.

# SPAIN

| | | |
|---|---|---|
| Waste Form | - | Vitrified HLW from reprocessing. |
| Geologic Media | - | Salt, clay, and crystalline rock. |
| Reference Canister | - | Carbon steel overpack (for crystalline only). |
| Buffer | - | Bentonite clay (for crystalline only). |
| Status | - | The siting process is currently studying favorable areas (AFA project) to define the suitability of each area and will be completed in 1994. |

# SWEDEN

| | | |
|---|---|---|
| Waste Form | - | Spent nuclear fuel. |
| Geologic Media | - | Crystalline rock. |
| Reference Canister | - | Copper / steel composite. |
| Buffer | - | Highly compacted bentonite. |
| Status | - | Volunteer siting process underway. A demonstration phase is planned, which includes constructing the encapsulation facility and the first phase of a repository for emplacement of a limited amount of waste. |

# SWITZERLAND

| | | |
|---|---|---|
| Waste form | - | Vitrified HLW from processing. |
| Geologic media | - | Crystalline rock and clay formation. |
| Reference canister | - | Thick walled steel overpack. |
| Buffer | - | Highly compacted bentonite. |
| Status | - | Currently assessing both crystalline rock and clay formations. NAGRA's main emphasis is on development of a low and intermediate level waste repository. |

# UNITED KINGDOM

Status - Disposal program on high-level nuclear waste is deferred, while Nirex concentrates on developing a low and intermediate level waste repository at the Sellafield site.

# UNITED STATES

| | | |
|---|---|---|
| Waste form | - | Spent nuclear fuel, minor amounts of commercially reprocessed vitrified HLW, and vitrified defense HLW. |
| Geologic media | - | Volcanic tuff. |
| Reference canister | - | A variety of alloys are being considered. |
| Buffer | - | None |
| Status | - | Site characterization is in progress in order to determine the suitability of the Yucca Mountain, Nevada site. Site suitability decision is now scheduled for 1998. |