Geologic Repositories

George M. Hornberger
Vanderbilt University

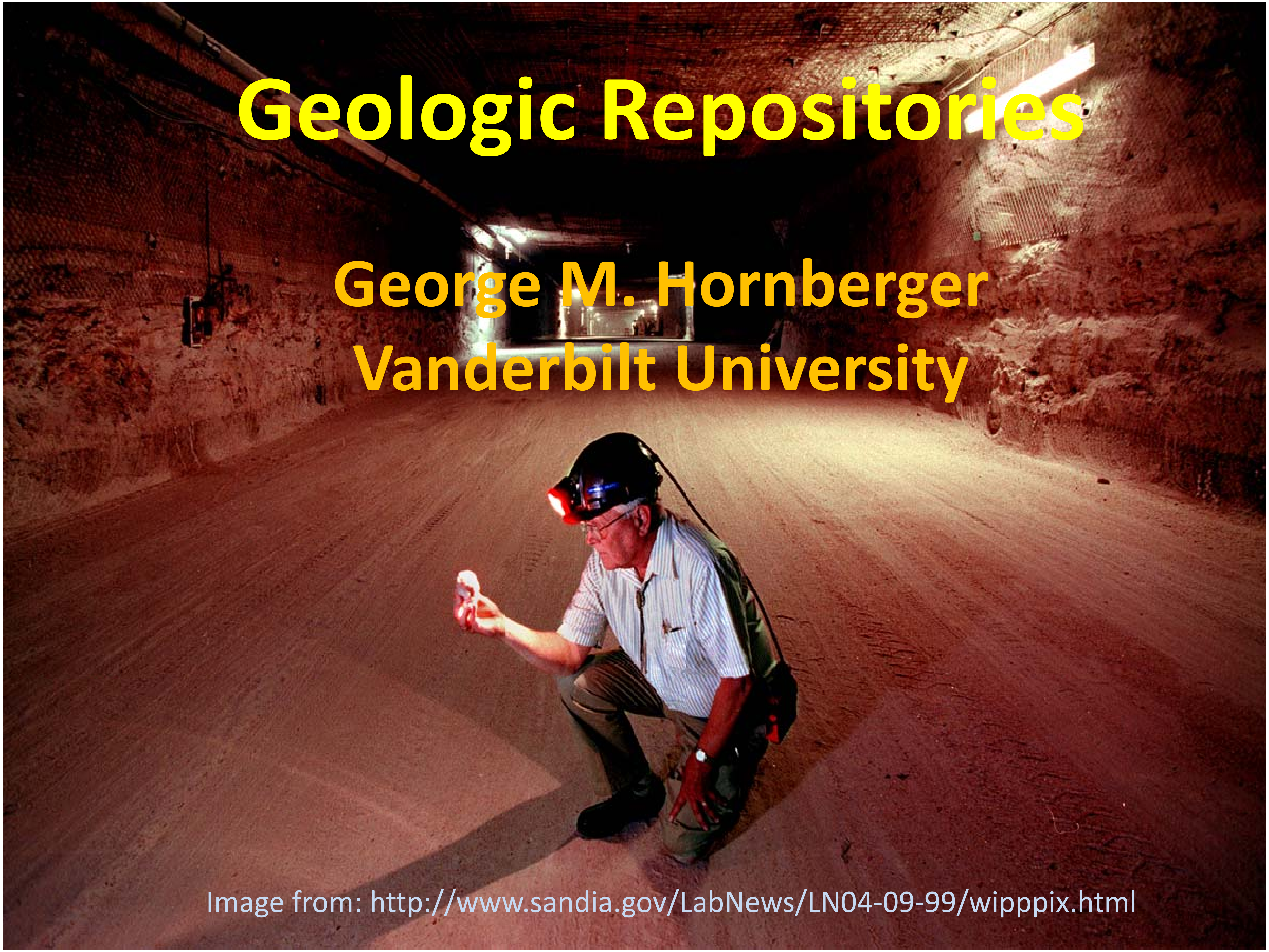
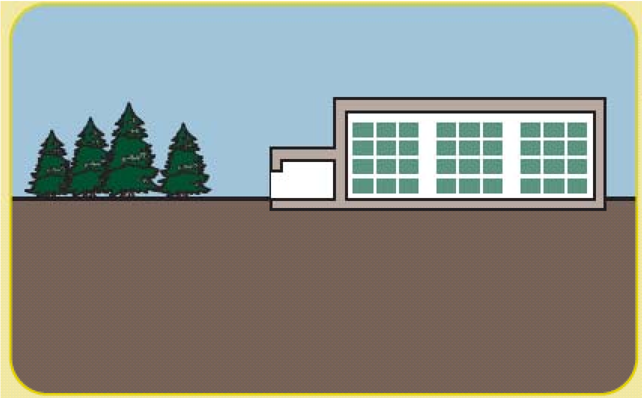


Image from: http://www.sandia.gov/LabNews/LN04-09-99/wipppix.html

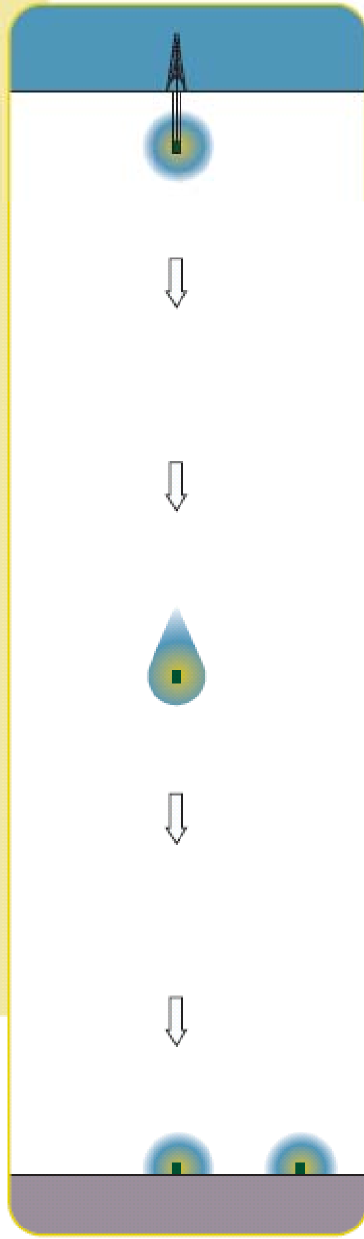
The Radioactive Waste Management Committee of OECD:

“from an ethical standpoint, including long-term safety considerations, our responsibilities to future generations are better discharged by a strategy of final disposal than by reliance on stores which require surveillance, bequeath long-term responsibilities of care, and may in due course be neglected by future societies whose structural stability should not be presumed.”

The Environmental and Ethical Basis of Geological Disposal of Long-Lived Radioactive Wastes, OECD Nuclear Energy Agency (1995)

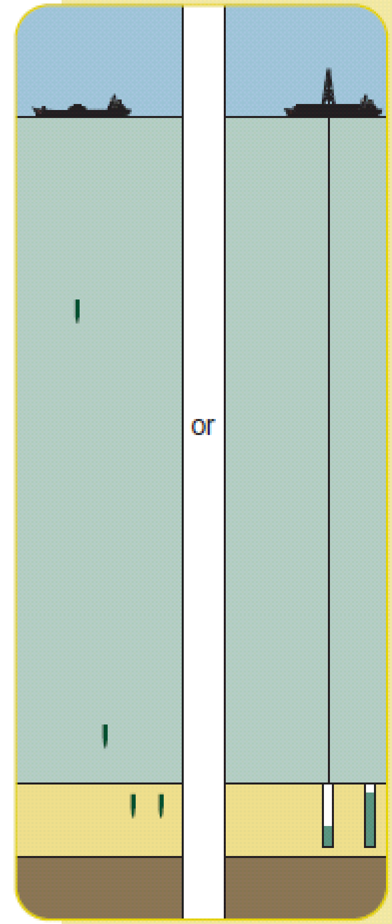


Surface storage



Disposal in ice sheets

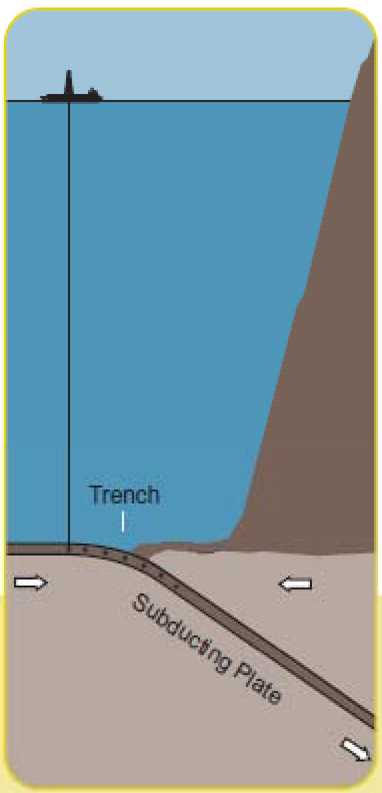
Ice sheets



Sub seabed disposal

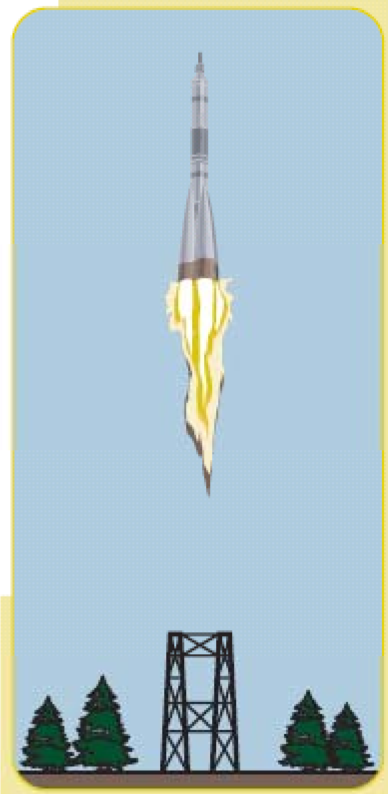
Surface storage

Seabed



Disposal at subduction zones

Subduction zone

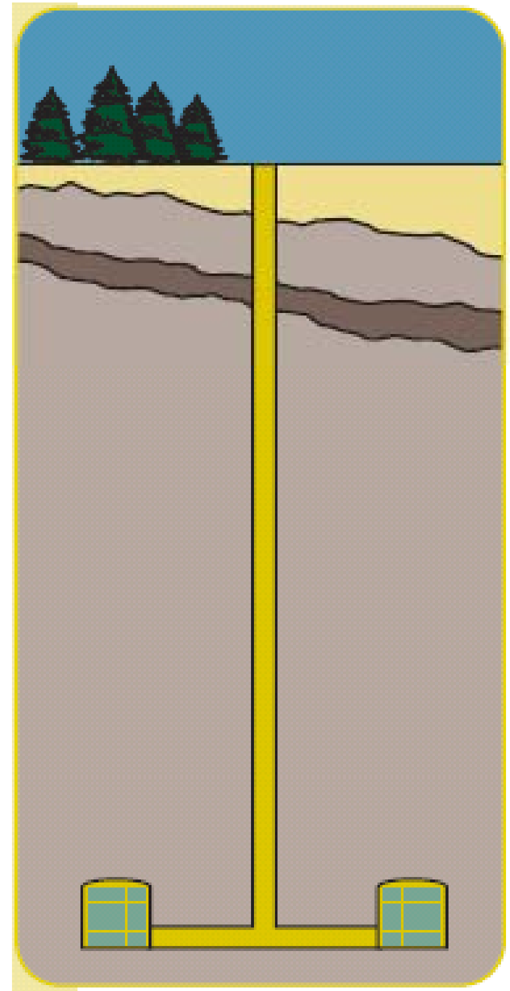


Disposal in space

Space

"It has been the technical consensus of most waste management specialists for several decades that geological disposal, using a system of engineered and natural barriers, is the preferred option of disposal for high level and long lived radioactive waste."

IAEA. http://www.iaea.org/OurWork/ST/NE/NEFW/wts_geologicaldisposal.html



Disposal in a deep underground repository

http://www.nda.gov.uk/documents/loader.cfm?url=/commonspot/security/getfile.cfm&pageid=10622 (Image)

Times suggested for assessments seem mind boggling.

"We believe that compliance assessment is feasible for most physical and geologic aspects of repository performance on the time scale of the long-term stability of the fundamental geologic regime — a time scale that is on the order of 10^6 years at Yucca Mountain."

Technical Bases for Yucca Mountain Standards
http://books.nap.edu/catalog/4943.html

Waste isolation – context for time frames for performance

Years BP	1000	10,000	100,000
World Population	50,000,000	1,000,000	Homo sapiens arrives
Life Expectancy	30	20	???
Events	First universities	End of last ice age	Ice age starts (~70Ka BP)

“Ideal “ site characteristics

Isolation:

- low rock permeability
- benign chemistry
- no mineral resources

Slow release

- long travel times of groundwater to where humans might contact contaminants

Need to understand long-term geological processes at a disposal site

- Tectonics – uplift, subsidence
- Earthquakes and faulting
- Igneous activity – volcanoes, magma intrusions
- Climate change – precipitation, glaciations
- Denudation – erosion processes
- Chemical alteration of rocks – water-rock interaction
- Groundwater flow

Wisconsin Ice Sheet ca 18,000 BP

U.S. – National Academy committee met in 1955-56 and issued a report in 1957: *The Disposal of Radioactive Waste on Land.*

Harry Hess, Chairman; John Adkins, William E. Benson, John C. Frye, William B. Heroy, M. King Hubbert, Richard J. Russell, Charles V. Theis

an amazing group – for example:

AGU awards the Harry H. Hess Medal
GSA presents the John C. Frye Environmental Geology Award
AGI presents the William B. Heroy Jr. Award
NGWA presents the M. King Hubbert Award
AAG presents the Richard J. Russell Coastal Geomorphology Award
AIH presents the C.V. Theis Award

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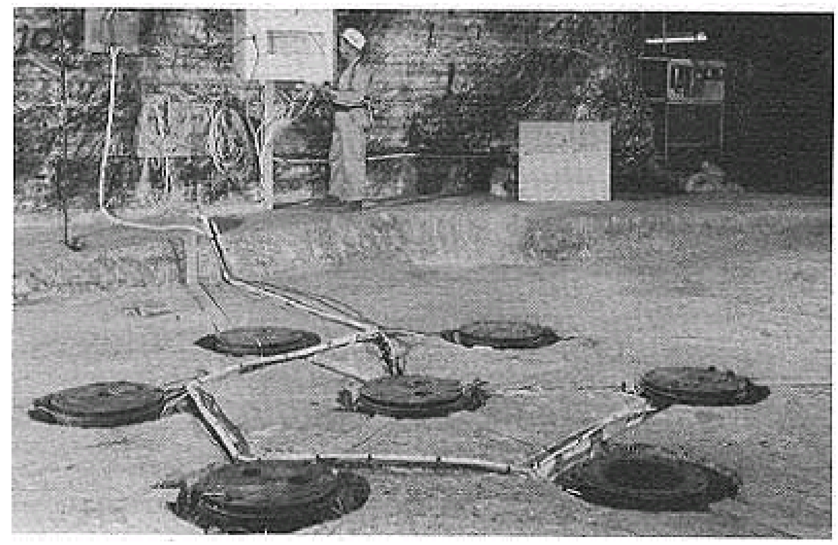
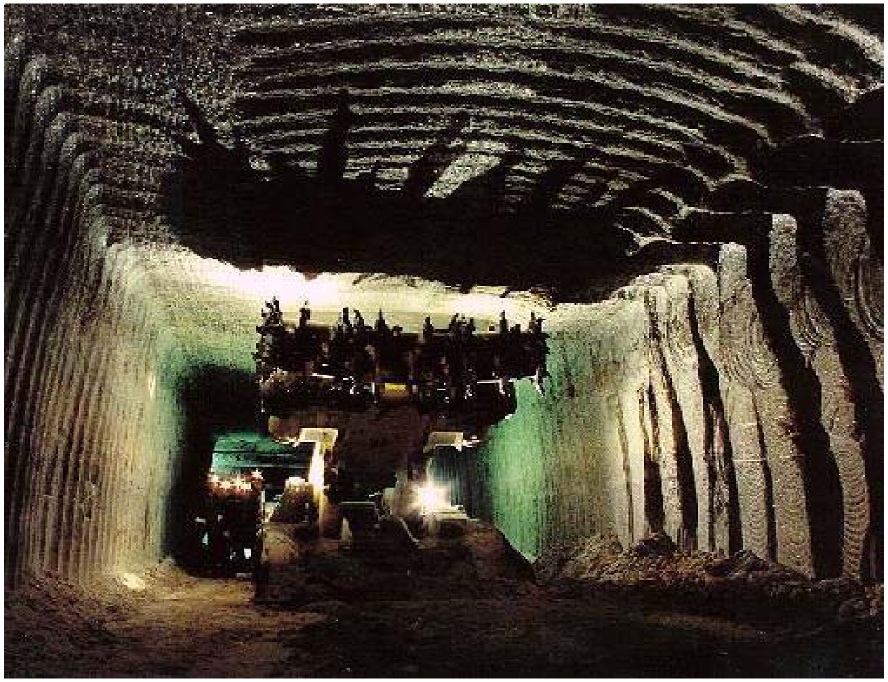
The most promising method of disposal of high level waste at the present time seems to be in salt deposits. The great advantage here is that no water can pass through the salt.



The Lyons salt mine and the AEC's demonstration project in the late 1960's.
http://www.kgs.ku.edu/Publications/Bulletins/227/12_six.html

Advantages of salt

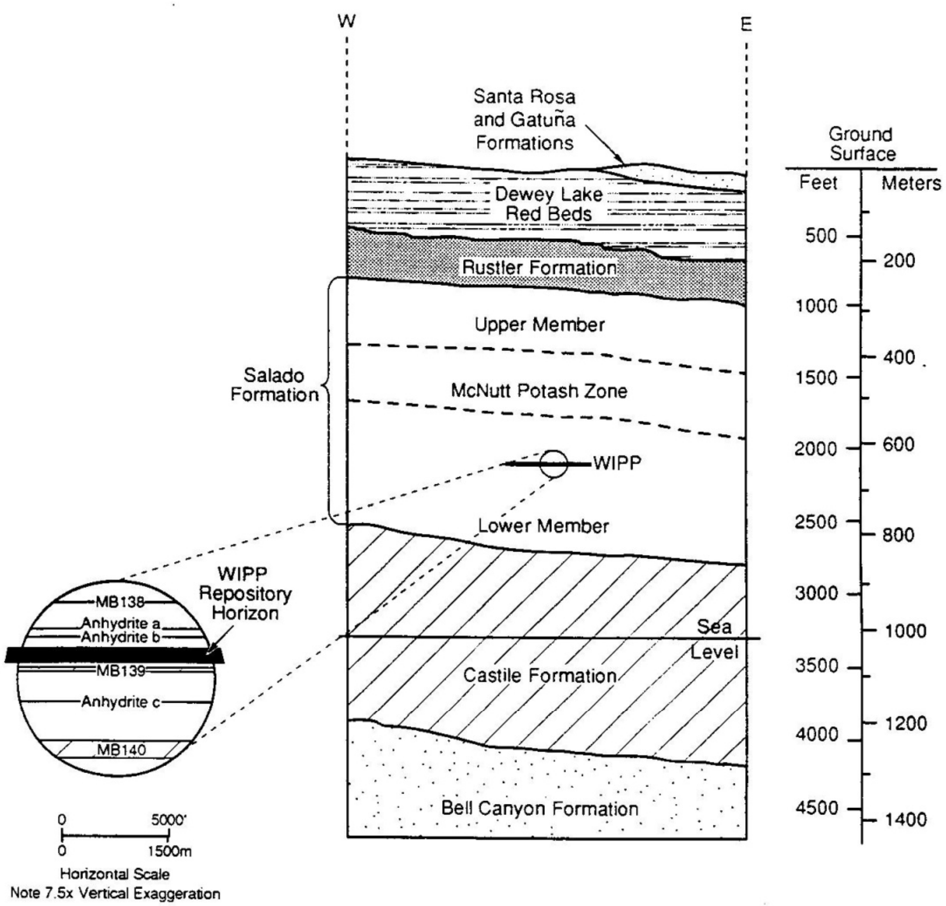


- Found in stable geological areas -- very little earthquake activity.
- Absence of flowing fresh water. (If water were present, salt would have dissolved.)
- Relatively easy to mine.
- Rock salt heals its own fractures because of its plastic quality. Salt will slowly move in to fill mined areas and seal radioactive waste from the environment.

WIPP

- The Waste Isolation Pilot Plant (WIPP) is in bedded salt approximately 658m below the ground surface near Carlsbad, New Mexico.
- WIPP is designed as a repository for defense-related transuranic (TRU) waste.
- WIPP is the first deep geological repository in the world to receive waste. (The first shipment was received on Mar 26, 1999.)

Formations at WIPP



Salt formations at the WIPP were deposited in thick beds during the evaporation of an ancient ocean, the Permian Sea. The primary salt formation (age ~ 240 ma) containing the WIPP mine is the Salado Formation. The Castile underlies the Salado. It is mainly anhydrite with thin limestone and halite layers. Overlying the Salado is the Rustler, with the Culebra Dolomite member as the aquifer of concern.

Extensive underground testing was conducted at the WIPP – reaction of salt to heating, rock mechanics studies, hydrogeologic studies

Rock types considered for geological disposal worldwide

ROCK TYPE	LOCATION
Salt	bedded (WIPP)
	domed (Germany)
Clay	plastic (Belgium)
	indurated (France)
Granite	Sweden; Finland
Tuff	Yucca Mountain, Nevada

Fig. 3: Properties of potential host rocks in Germany which are relevant for repository concepts

Property	Rock salt	Clay/ argillaceous rock	Crystalline rock (e.g. granite)
Thermal conductivity	High	Low	Medium
Permeability	Practically impermeable	Very low to low	Very low (unfractured) to permeable (fractured)
Strength	Medium	Low to medium	High
Deformation behavior	Visco-plastic (creep)	Plastic to brittle	Brittle
Stability of cavities	Self-supporting	Artificial reinforcement required	High (unfractured) to low (highly fractured)
In-situ stress	Isotropic	Anisotropic	Anisotropic
Dissolution behavior	High	Very low	Very low
Sorption behavior	Very low	Very high	Medium to high
Heat resistance	High	Low	High

Favorable property — Average — Unfavorable property

http://www.bmwi.de/English/Redaktion/Pdf/final-disposal-of-high-level-radioactive-waste,property=pdf,bereich=bmwi,sprache=en,rwb=true.pdf

Underground Research Laboratories -- examples

- (HADES) in the Boom Clay, Belgium
- Bure in the Callovo-Oxfordian clay, France
- Grimsel in the granitic rock of the Aar Massif, Switzerland
- Hard Rock Laboratory (HRL) at Äspö, Sweden
- Horonobe in Koetoi and Wakkanai argillaceous formations, Japan

Multiple barrier concept – engineered components in concert with geology

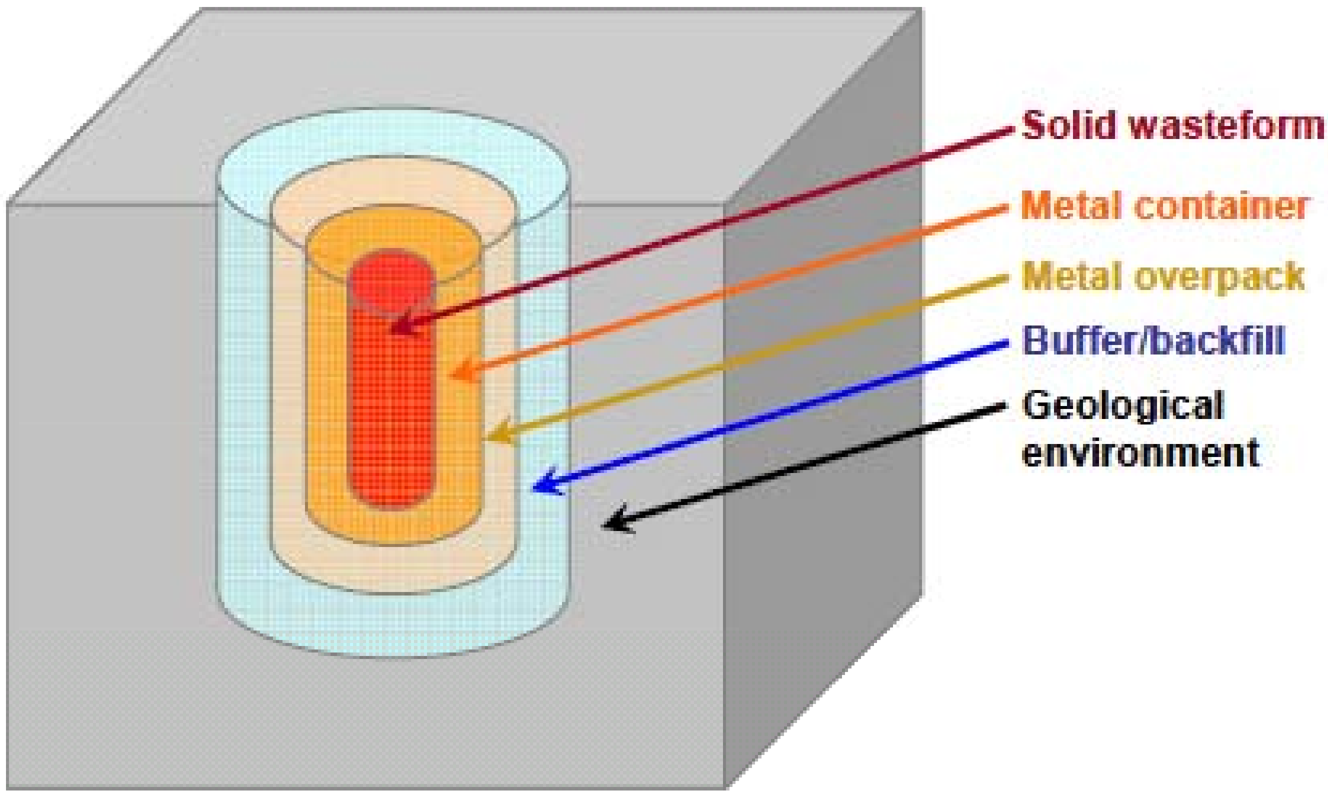


Image: Baldwin, T, Chapman, N, and F Neall 2008. Geological Disposal Options for High-Level Waste and Spent Fuel. Report for the UK Nuclear Decommissioning Authority

Post-closure safety assessment

• Analyze the performance of a repository to show, with an appropriate degree of confidence, that it will remain safe over a prolonged period, beyond the time when active control of the facility can be relied on.
• Develop an understanding of how, and under what circumstances, radionuclides might be released from the repository, how likely such releases are, and what the radiological consequences of such releases could be to humans and the environment.
• Understand how the geological characteristics of the site and the components of the design function in concert to prevent, lower the likelihood of, or attenuate such releases.
• Collate data, develop models and perform analyses related to safety.

Adapted from: http://www.nea.fr/html/rwm/reports/2004/nea3679-closure.pdf

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The Committee is convinced that radioactive waste can be disposed of safely in a variety of ways and at a large number of sites in the United States. It may require several years of research and pilot testing before the first such disposal system can be put into operation.

Reality strikes? –
1975-76: ERDA proposed an ambitious plan – siting and development of as many as 6 repositories. First two in salt to begin pilot-scale operation by 1985. The next four in other rock types, notably shale and granite. Site investigations proposed for 36 states caused much turmoil.

U.S. – National Academy committee *The Disposal of Radioactive Waste on Land.*

We stress that the necessary geologic investigation of any proposed site must be completed and the decision as to safe disposal means be established before authorization for construction is given. Unfortunately such an investigation might take several years and cause embarrassing delays in the issuing of permits for construction.

A bit of the U.S. history U.S.

- *1970's => false starts*
- *Nuclear Waste Policy Act of 1982*
- *1986 => from 9 to 5*
- *Nuclear Waste Policy Amendments Act of 1987*
- *2002 – site suitability*
- *2008 – license application*
- *2009 – ??*

Current status for deep geological repositories for HLW and spent fuel

- Yucca Mountain – license application pending at NRC, but “not acceptable” policy of current administration
- Sweden – site selected at Forsmark
- Finland – site selected at Olkiluoto Nuclear Power Plant
- Other countries are doing research, many at underground research laboratories, but have not selected a disposal site.

"The challenges we face in some ways make up a 'Catch 22' situation: on the one hand, the lack of public confidence in the management and disposal of spent fuel and high level radioactive waste hampers the effectiveness and efficiency of national efforts to construct geological repositories; on the other hand, in order to substantially increase public confidence, the nuclear community must have one or more operational geological repositories in which waste disposal technologies can be successfully demonstrated. But despite this 'Catch 22', we can continue to make progress — and it is my view that, once the first country or countries have succeeded in placing a geological repository in service, the road ahead for other countries will be made much easier. In that sense, all members of the international community have a stake in the success of those national programmes that are the most advanced."

http://www.iaea.org/NewsCenter/Statements/2003/ebsp2003n028.html


We have to bury it as far as possible from the nearest election.