

Knowledge preservation for nuclear waste repositories

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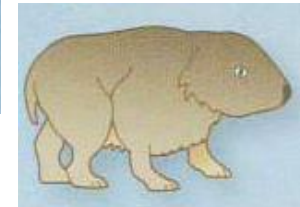
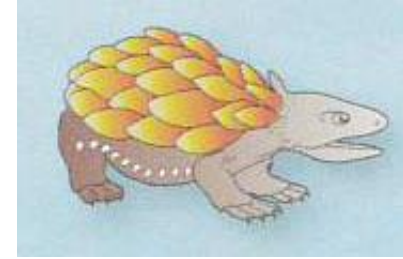


Introduction

- In deep geological repositories high radioactive nuclear waste has to be isolated for up to one million years – an unimaginable long period. After a repository is closed, a phase of active control is foreseen (up to a few hundred years), and after that passive control (up to 1,000 years) – and after that?
- How can human unintentional intrusion in a sealed repository be prevented?
- Is it necessary to and if yes how can future generations be informed about nuclear waste and how to handle possible leakages?
- Nuclear waste directive 2011/70/Euratom instructs Member States to develop concepts for long-term knowledge preservation.

A short look into the future

- Homo erectus emerged about 1.8 million years ago
- No noteworthy continental drift in next 1 million years
- Next predicted ice-age in 15,000 years or later
- Changes in biodiversity due to climate changes
- Artificial intelligence will continuously change human life
- Humans possibly will die out in next five million years (or earlier: Stephen Hawking: 1,000 years)
- Mass extinction by mega-volcanic eruptions or meteorites: unpredictable, but possible
- Not one future, but a lot of possible futures



Safety concept for geological repositories

- Technical barrier (containers etc.)
 - Example Sweden: 2018 Swedens Environmental Court rejects application to build geological repository in Forsmark due to the fact that the safety case of copper canisters cannot be proven (may corrode even after a few hundred years even in oxygen-free environment)
- Geological barrier
 - Clay, salt, granite
- The long-term safety of both has not been proven by now, and perhaps never will be, therefore a third barrier is necessary:
- “Social barrier”
 - Prevent human intrusion (incl. robots)
 - Conserve knowledge about the repository over very long time

Research on knowledge preservation

1980-1984:
USA: Human
Interference
Task Force
(HITF)

1993: Update
of HITF results
for use in
WIPP Plant

Since 2011:
NEA-OECD
project

1982-84:
Germany:
Nuclear
semiotics

Since 2010: F:
ANDRA's
memory-
preservation
project

USA: Human Interference Task Force (HITF)

- HITF was created by US Department of Energy in 1980, scientists from many disciplines were involved, also semiotics
- Aim: develop a method to warn future generations for **up to 10,000 years** not to intrude waste site
- Direct drilling of a borehole in the sealed repository is seen as the biggest interference risk:
 - Based on historical drilling rates in the region of WIPP, between 67.3 and 148 boreholes per square kilometre over the 10,000 year period are predicted.
- In 1984, results were published in a technical report.

HITF: Results

- Icons and written language
- Messages should have four levels: Caution message – simple written message – detailed message – detailed technical information
- Redundancy
- Material duration was researched
- Site selection was considered

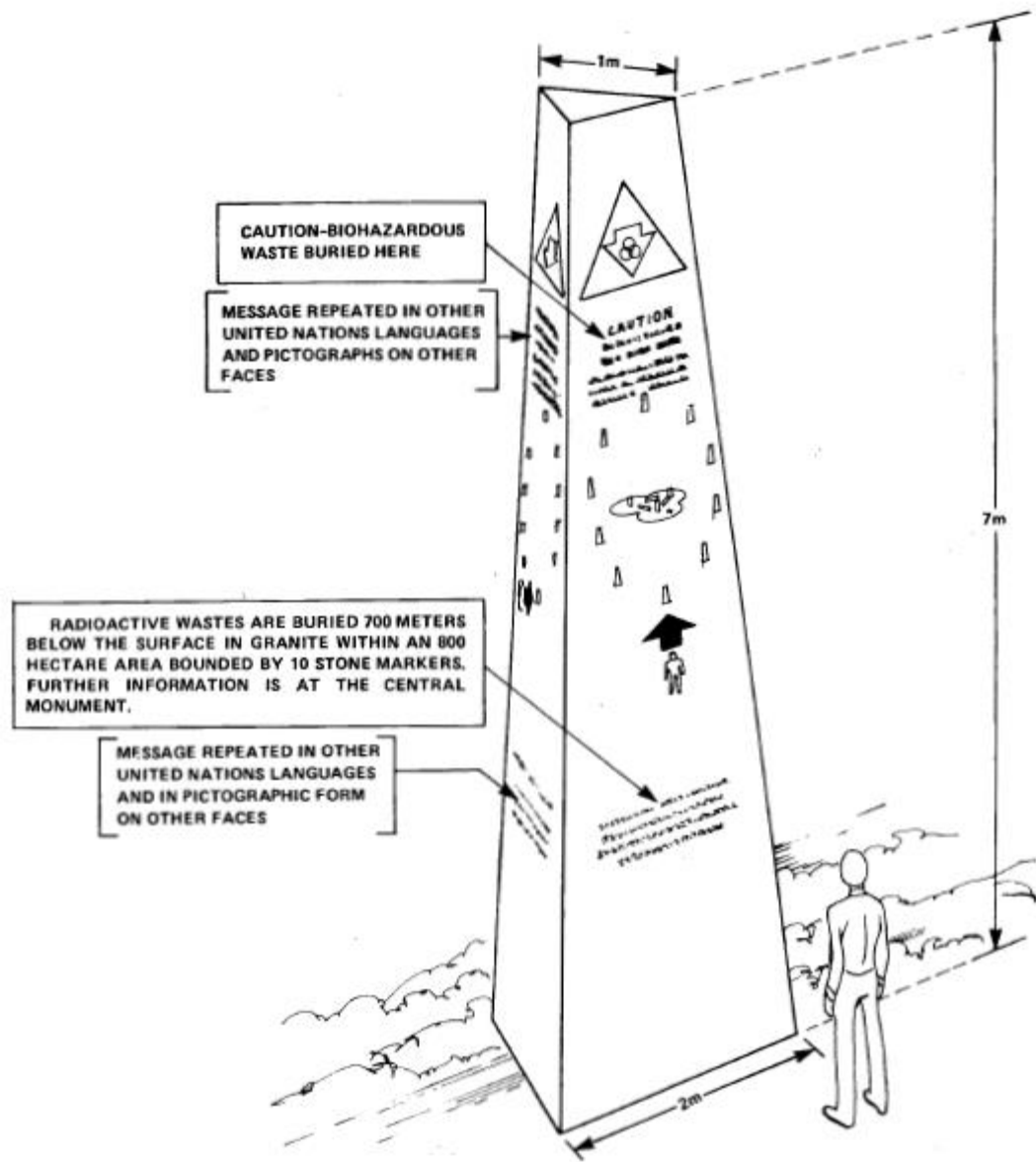


FIGURE 7-2. PERIPHERAL MARKER MESSAGE

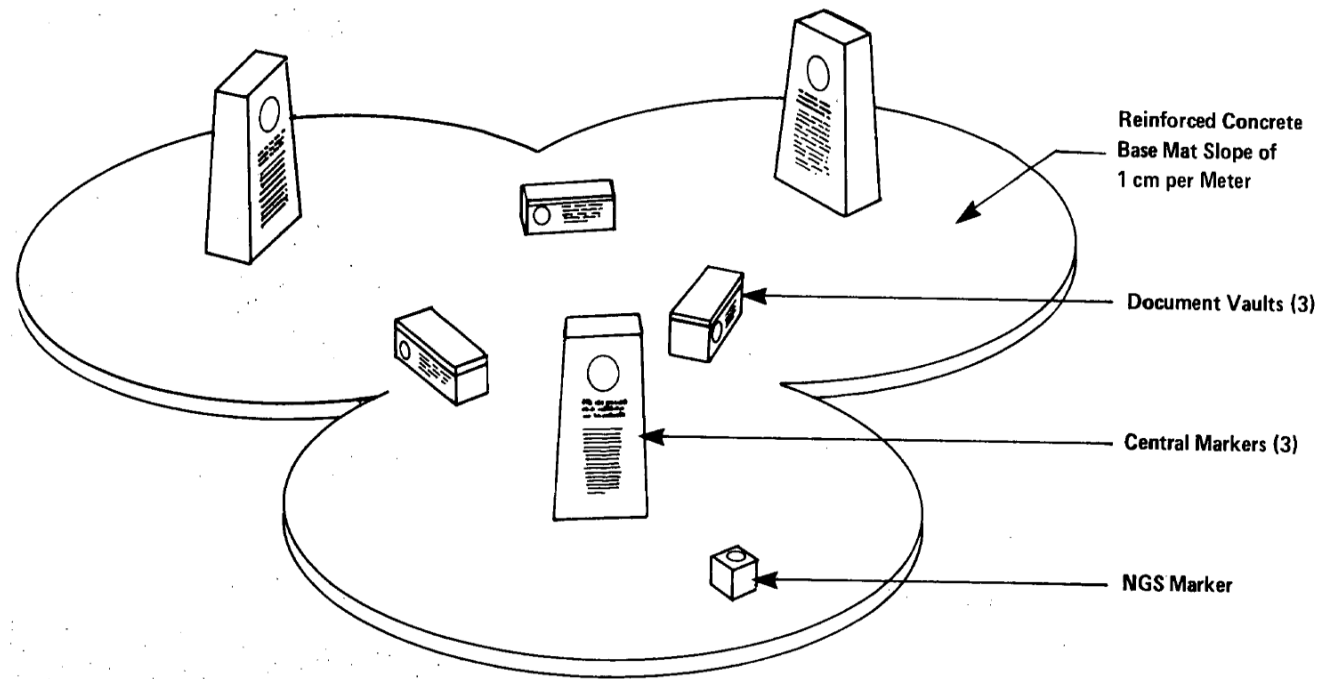


FIGURE 7-3. CENTRAL MONUMENT

Figures from HITF 1984, p. 80-81

Update 1993 for use in WIPP

- Waste Isolation Pilot Plant (WIPP) in New Mexico : repository for military transuranic waste like Plutonium, disposal in a salt bed
- 2 Teams worked in parallel on development of a concrete concept for warning and informing future generations of WIPP
 - Warning markers without writing, include faces and humans into markers
 - Spike fields, forbidding blocks, menacing earthworks...



DANGER
POISONOUS RADIOACTIVE WASTE BURIED HERE
DO NOT DIG OR DRILL HERE BEFORE 12,000 A.D.



Figure 4.5-4. Proposed Level II message. The face to the right is reprinted with permission from Eibl-Eibesfeldt, Iranäus. *Human Ethology*. (New York: Aldine de Gruyter) Copyright © 1989 by Iranäus Eibl-Eibesfeldt.

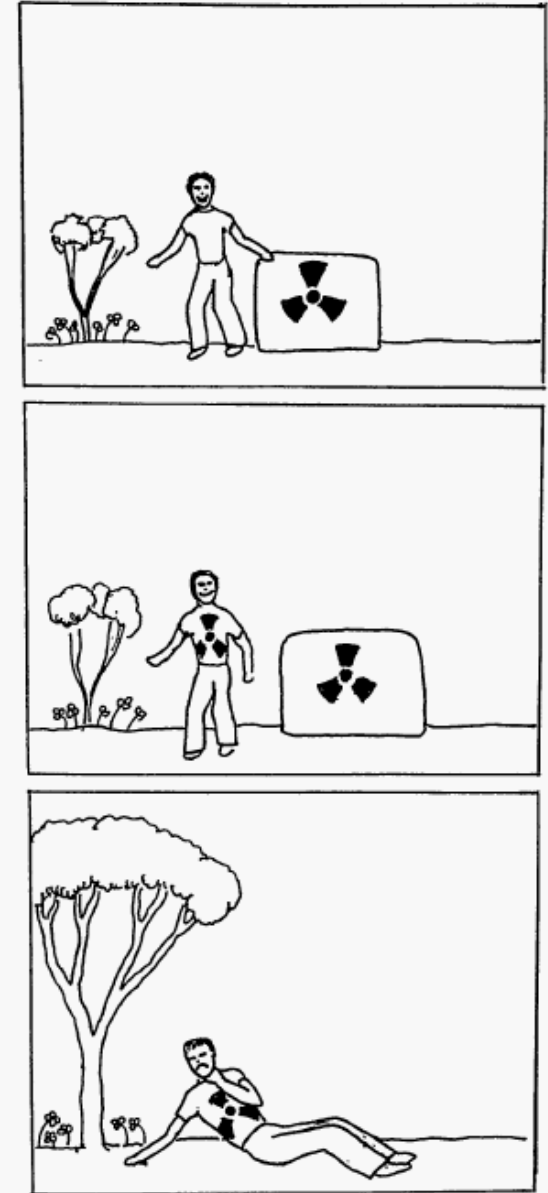


Figure 7. Pictographic Definition of Symbols—Radiation Trefoil (art by Jon Lomberg).



Michael Brill &
Safdar Abidi:
Landscape of
Thorns
<http://pictify.saatchigallery.com/1147839/michael-brill-safdar-abidi-landscape-of-thorns>

SPIKE FIELD

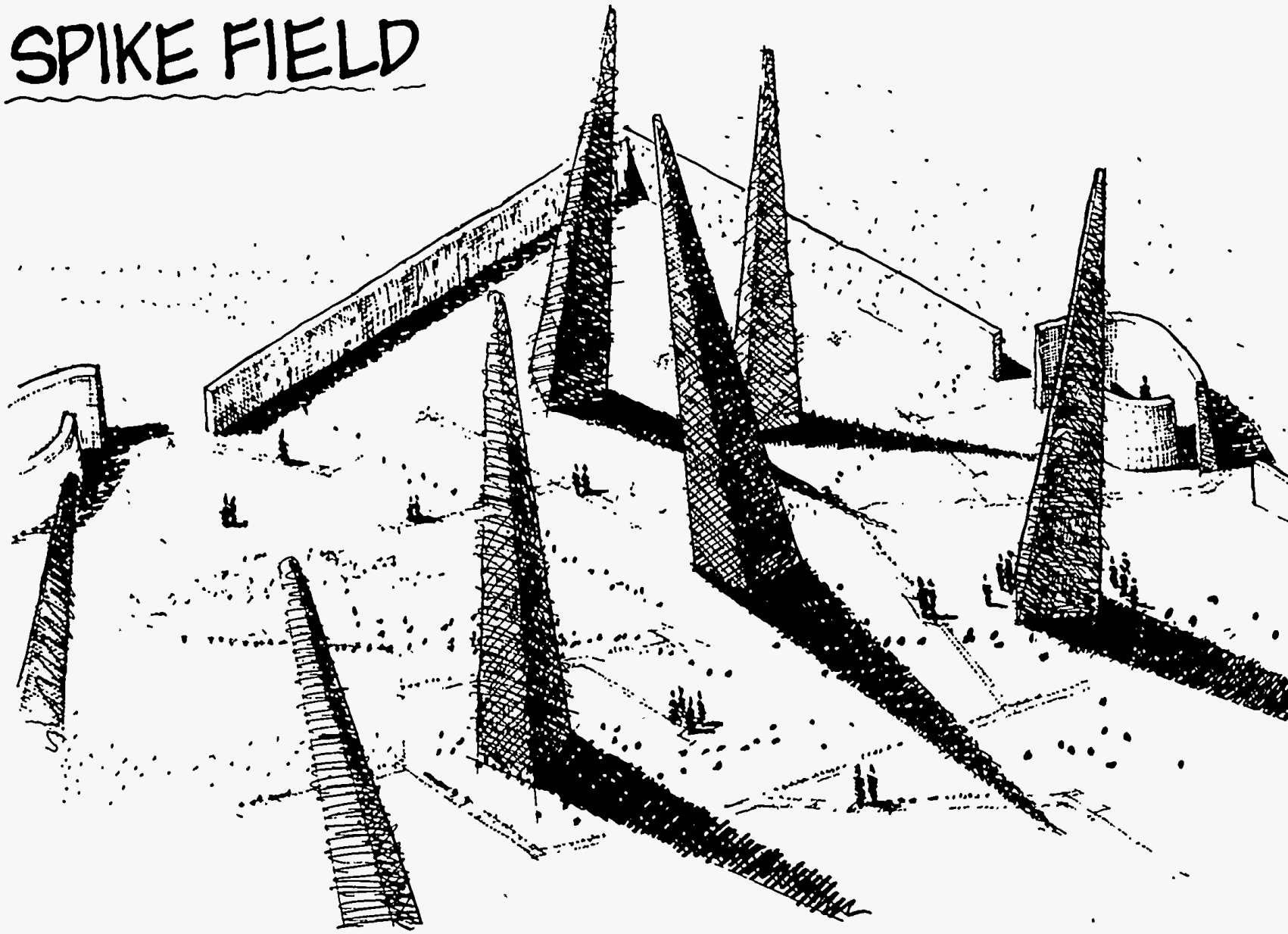


Figure 4.3-3. Spike Field, view 1 (concept and art by Michael Brill).

Figures from
Trauth et al. 1993

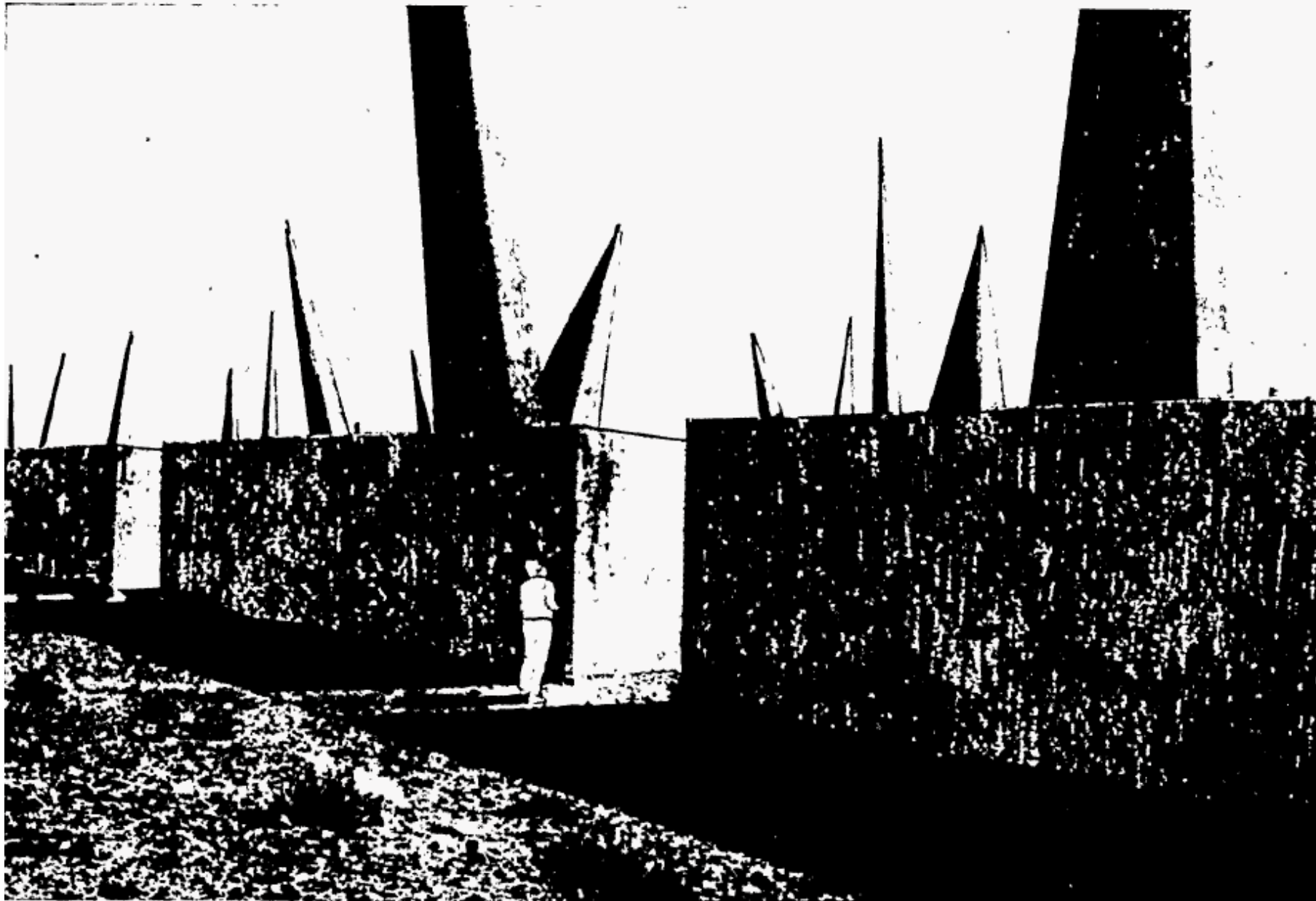
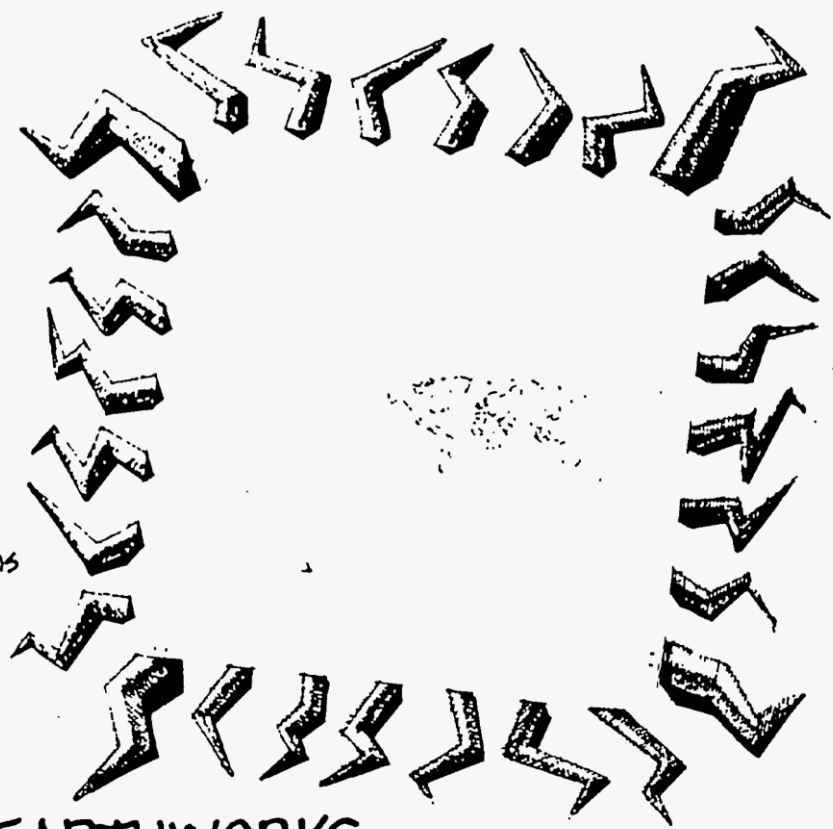


Figure 4.3-4. Spike Field, view 2 (concept by Michael Brill and art by Safdar Abidi).

Figures from
Trauth et al. 1993



- World map of other burial sites
- hot cell left to decay
- vantage points for panoramic view at tops of 4 major berms

MENACING EARTHWORKS

Figure 4.3-8. Menacing Earthworks, view 1 (concept and art by Michael Brill).

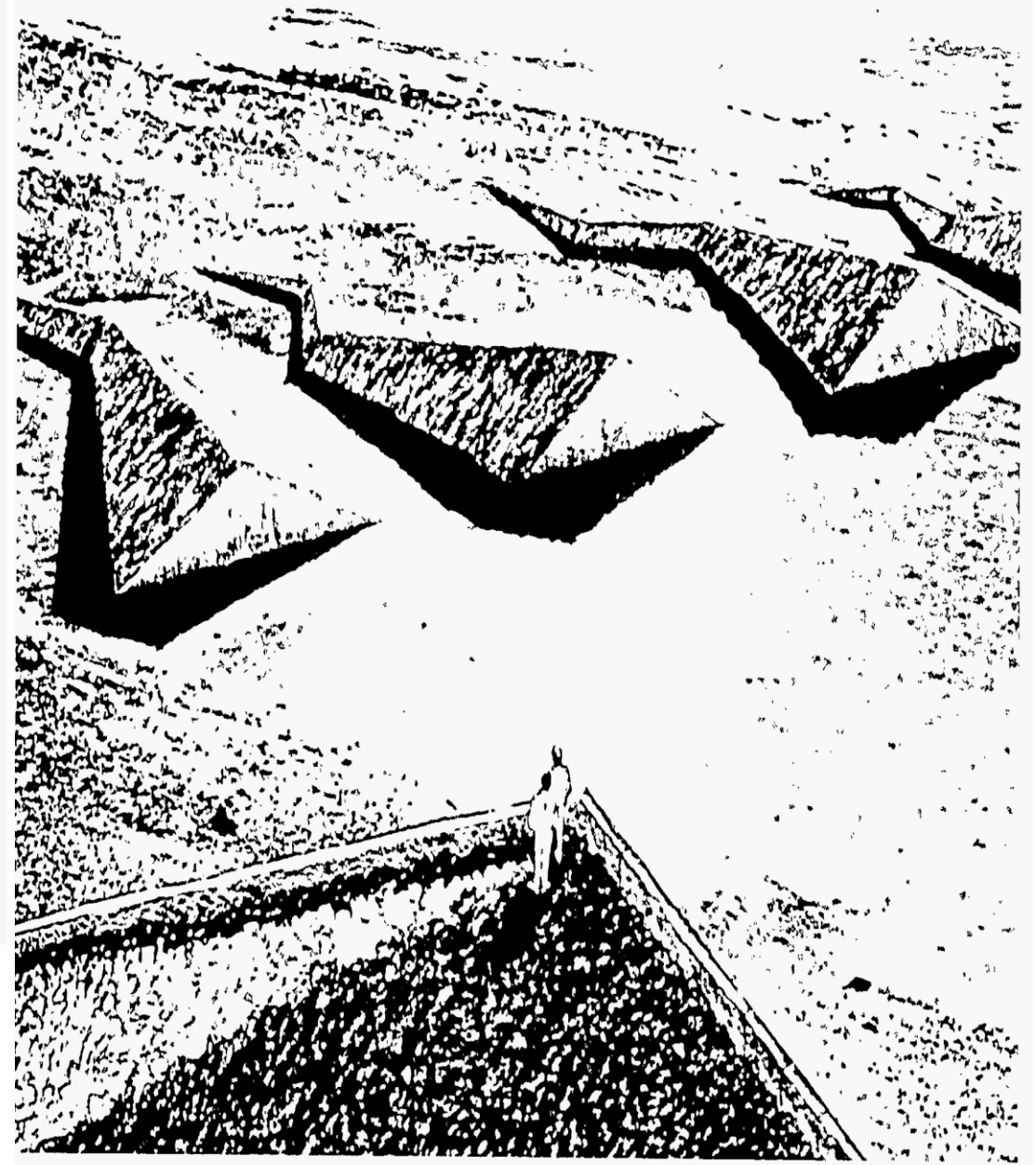


Figure 4.3-9. Menacing Earthworks, view 2 (concept by Michael Brill and art by Safdar Abidi).

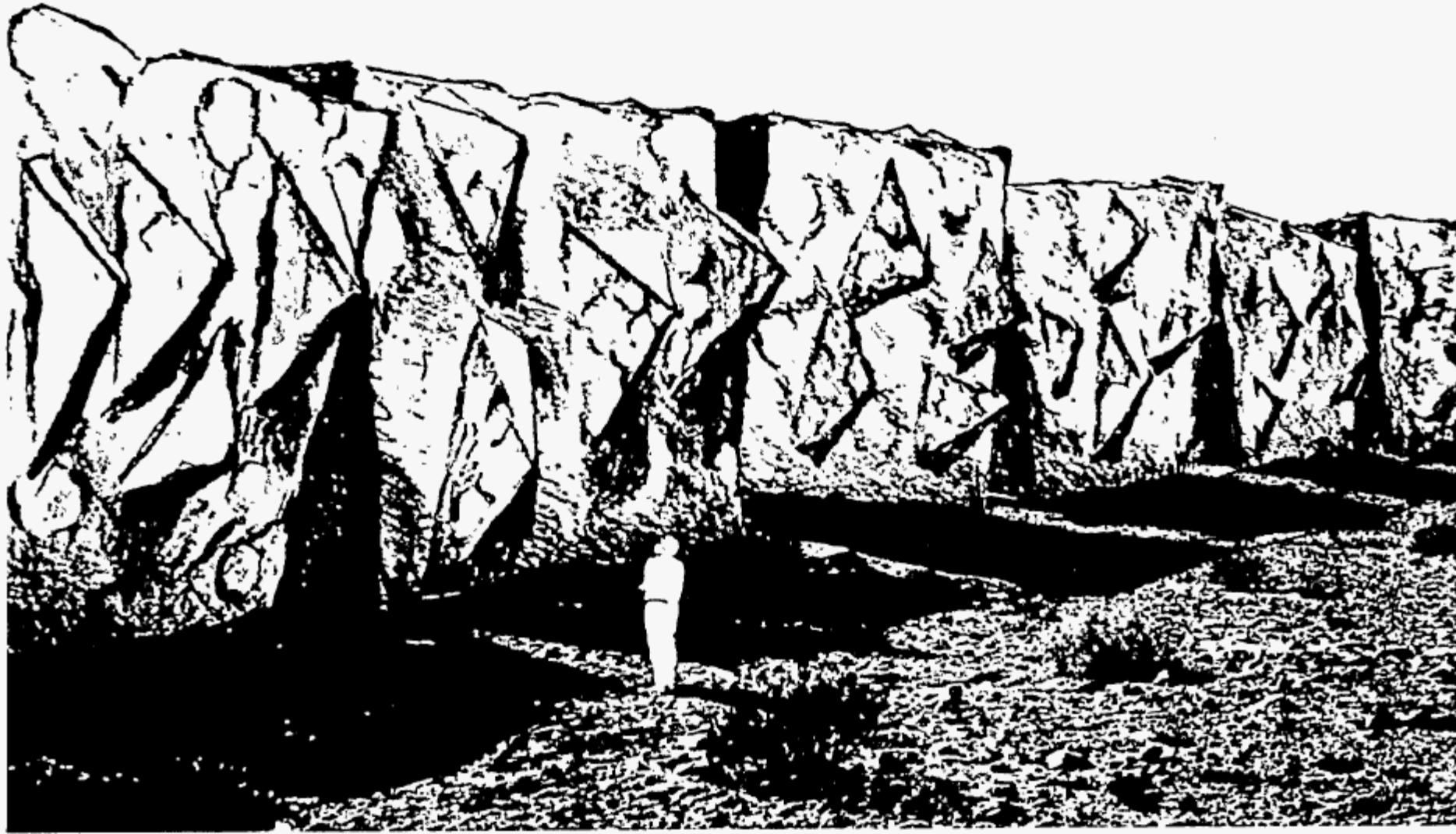
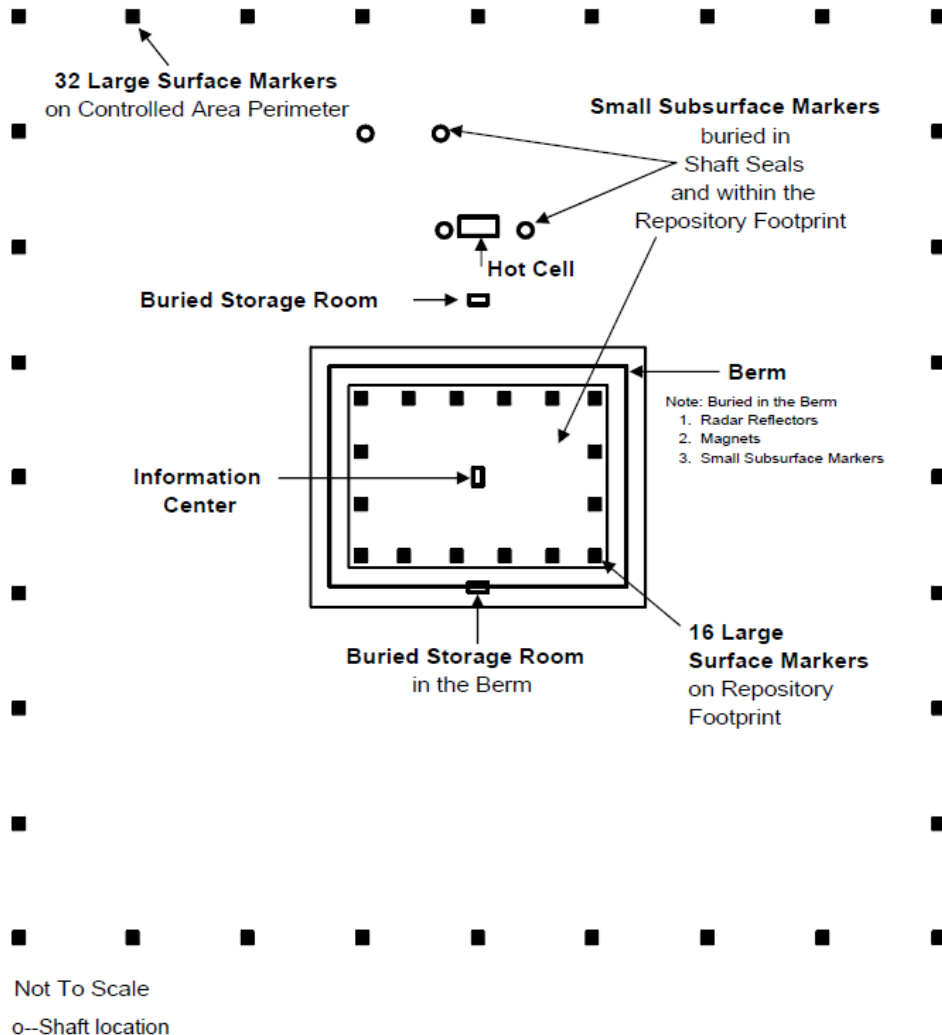


Figure 4.3-15. Forbidding Blocks, view 2 (concept by Michael Brill and art by Safdar Abidi).

Figures from
Trauth et al. 1993

WIPP – Permanent Markers Implementation Plan 2004

DOE/WIPP 04-3302



EPA approved a permanent marker system of 32 monoliths with 7m height that will secure the site with an information centre in the middle.

Figure 2. Permanent Markers Components

Status of the Permanent Markers at WIPP?

- WIPP will be closed in the early 2030-ies.
- First 100 years after closure: WIPP is mandated by law to institute active controls with fences, gates, and armed guards on patrol.
- “Building markers and monuments that are out of proportion to the risk being presented to the future is not in keeping with generational equity.”
- Now the programme is being evaluated. (Patterson et al. 2013)

Birth of nuclear semiotics in Germany

- Book of Roland Posner: "Warnungen an die ferne Zukunft". 2007
- Is based on a questionnaire that was sent to 12 semiotic scientists from „East and West“ from 1982-1983
- Question: "How is it possible to inform our descendants in the next 10,000 years about the sites and specific dangers of nuclear waste?"

Proposed solutions

- Artificial moon
- Archive in the cellar
- Secured data media (for prevention of breaking the code by unauthorized persons)
- Genetics: mathematical code on biological matter
- Genetically manipulated cats
- Sirens
- Optical warnings
- Dissemination of myths, fairy tales and legends
- Monuments with updated warning signs in new languages over the centuries
- Nuclear priests

France: ANDRA's memory preservation project

- ANDRA = French National Radioactive Waste Agency
- Two activities:
 - Memory preservation up to 1,000 years for CSM and CSFMA disposal
 - Multi-millennial scale memory preservation for future spent fuel and high level waste repository
- Passive systems:
 - All records are stored at two different sites
 - Records are printed on permanent paper which should last over centuries
 - Records are updated every five years for the whole oversight period (500 years)
 - Land is restricted from use by legal means
- Active systems
 - Based on communication with the public, esp. with local information committees (CLI)
- Patrick Charton developed a sapphire disc which is immune against wearing out; 4,000 pages of information can be stored on it and afterwards read with a microscope.

NEA-OECD project “Preservation of records, knowledge and memory across generations” (RK&M)

- First phase 2011-2014, second phase 2014-2018
- Members are: ONDRAF/NIRAS (Belgium), SCK (Belgium), NWMO (Canada), SURAO (Czech Republic), STUK (Finland), ANDRA (France), BfS (Germany), GRS (Germany), KIT (Germany), PURAM (Hungary), JAEA (Japan), RWMC (Japan), ENRESA (Spain), SKB (Sweden), Riksarkivet (Sweden), SSM (Sweden), NAGRA (Switzerland), SFOE (Switzerland), NDA-RWM (UK) and USDOE (USA).
- Literature survey from Swiss institute INA from 2010 was used as basis
- First international conference in 2014
 - Participation of artists
 - No participants from Africa, South America and large parts of Asia

Results from RK&M project

- 7 guiding principles for RK&M preservation, among them:
- Planning for the knowledge preservation should start while designing waste management plans (= now!) when funding is available
- Agreements with societal institutions and international bodies should be reached that are likely to survive beyond the closure of the repositories and end of operation of nuclear waste institutions
- Final report could be available soon

Testing of symbols

- Biohazard symbol 1967
 - You tube „Why dangerous symbols can't last forever“ (VOX 99% invisible): <https://www.youtube.com/watch?v=IOEqzt36JEM>
 - Tested by 300 persons from USA: gender, income, education
- New IAEA radioactive symbol:
 - Introduced 2007
 - Tested by the Gallup Institute on 1,650 individuals in Brazil, Mexico, Morocco, Kenya, Saudi Arabia, China, India, Thailand, Poland, Ukraine, USA; also mixed by gender, age, educational backgrounds

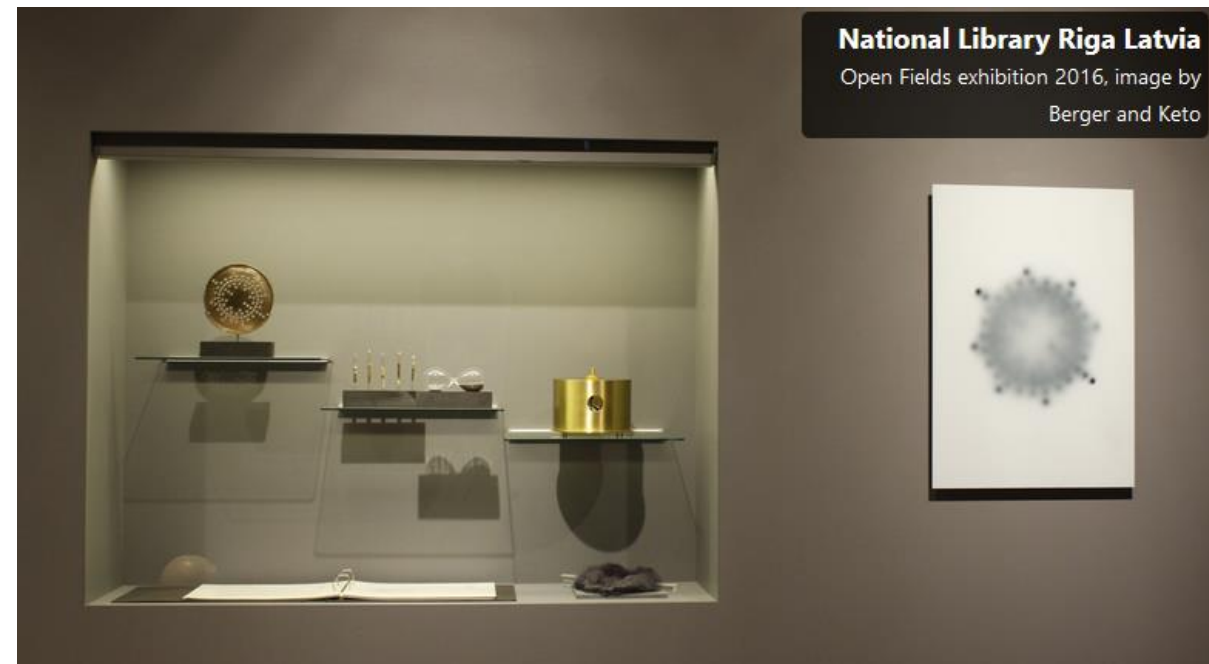


Rolling Stewardship – concept of Canadian Coalition for Nuclear Responsibility (CCNR)

- Humans can contain waste security for decades at a time – but not longer
- There is no solution to the waste problem right now – perhaps there will be in future
- Therefore the nuclear waste should not be abandoned in the repository
- Every 20 years it will be controlled and if need be re-packaged
- It is an ongoing reminder, information can easily be transmitted to the next generation

Inheritance project "OPEN CARE" by Erich Berger and Mari Keto

- OPEN CARE is a set of artefacts which propose a social thought experiment: what if nuclear waste were a very personal responsibility and thus part of our everyday life?
- A small nuclear waste container holds Am-241 encapsulated in steel. It also includes instructions for caring = how to measure the remaining radioactivity (electroscope, gold leaf, electrostatic rod, fur to charge it)
- If instructions are no longer understandable they shall be renewed during caring.



Long-term perspectives in national waste management programmes

- According to Article 12(1)e of the Directive, Member States are to define the concepts or plans for the post-closure period of a disposal facility's lifetime, including the period during which appropriate controls are retained and the means to be employed to preserve knowledge of that facility in the longer term.
- Of the Member States with nuclear programmes, only a few have presented detailed post-closure plans mainly for near-surface disposal facilities while **post-closure measures for deep geological facilities are either not foreseen or not addressed**. Information on the Member States' approach towards preservation of knowledge after the closure of disposal facilities is limited in most of the national programmes. **This is an area that Member States should develop further in their national programmes.** (EC Report 2017, p. 12)

Conclusions

- Some research is conducted, but transfer into policy and practice is far behind
- It is questionable if research from US and European viewpoints is suitable for global practice
- A few concepts for knowledge preservation over a few hundred years exist
- No convincing concept exists for very long periods
- EU member states urgently need to develop down-to-earth concepts for active and passive institutional control periods, and also for long-term knowledge preservation
- Take RK&M recommendation seriously: future preservation has to be researched and designed now when funds are available.
- Institutionalized participation of civil society in these topics is missing, civil society will be in charge of preserving knowledge after institutional oversight will have been terminated
- Is it responsible to let the people find solutions that have caused the problem? (Hausner in Posner 2007, p. 13)

Questions to discuss

- Can and should the knowledge on the repositories be preserved at all?
- Who should be responsible for the long-term knowledge preservation after end of institutional control?
- How should the anti-nuclear movement and independent experts participate?
- New cooperation partners from sustainability institutions?

Contact

- Thank you for your attention!
- The study will be published in the next weeks at http://www.ecology.at/wua_endlager_wissenserhalt.htm.
- Contact:
 - Gabriele Mraz: mraz@ecology.at
 - David Reinberger: david.reinberger@wien.gv.at

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