Implications of Host Rock Selection for a HLW Repository System in Germany - Consequences for Repository Design and Safety -

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Outline of Presentation

- Repository Site Selection Act
- State of the Art in Repository Design
- Comparison of Repository Systems
- Impact of Host Rock Selection on Repository Design and Safety
  - Rock Salt
  - Clay Formations
  - Crystalline Rock
- Summary and Conclusions

Repository Site Selection Act

- **"Gesetz zur Suche und Auswahl eines Standortes für ein Endlager für Wärme entwickelnde radioaktive Abfälle und zur Änderung anderer Gesetze (Standortauswahlgesetz - StandAG)"**

  passed by the German Parliament (Bundestag) last summer; published on July 23, 2013

- **The aim of the law is:**

  to use a scientifically based and transparent procedure to find a repository site - in particular for high-level radioactive waste - that provides the best level of safety for a time period of 1 million years

Repository Site Selection Act

- **Prior to the start of the selection procedure:**
  - **implementation of a commission (April 10, 2014) (Kommission Lagerung hoch radioaktiver Abfallstoffe),**

    which has to conclude on a report for the site selection procedure (options and recommendations) until end 2015 / mid 2016

- **Challenge:**
  - **How to compare the safety level of potential sites for a HLW repository in different geologic environments?**

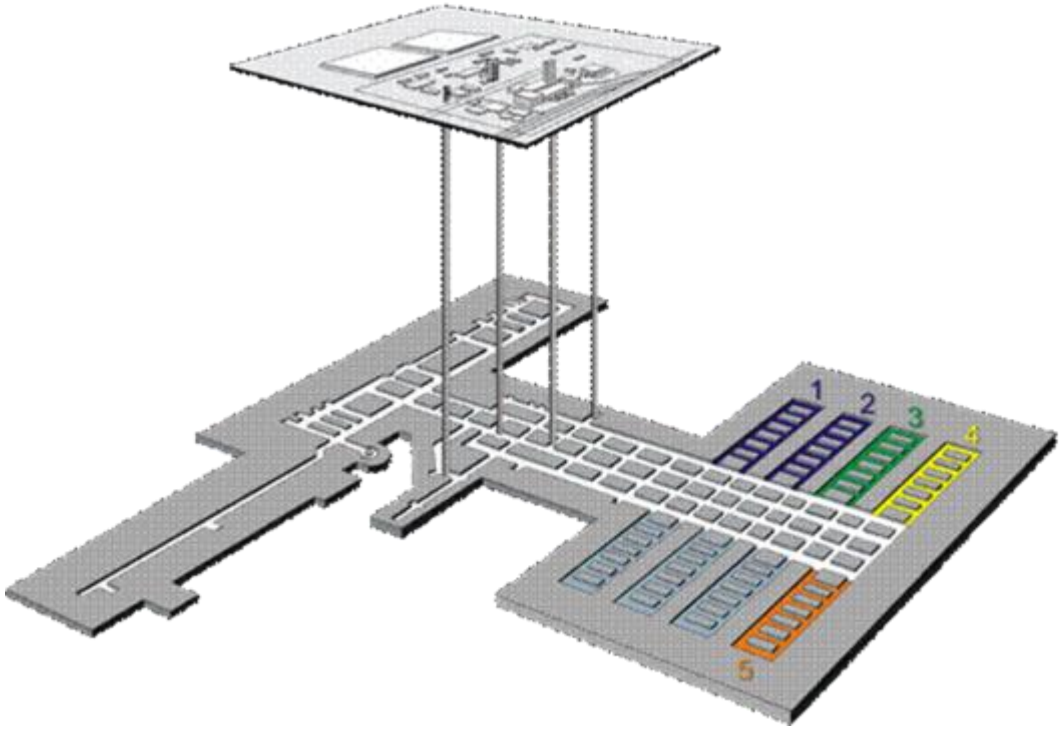
State of the Art in Repository Design

- There is international consensus (e.g.: OECD/NEA, IAEA) that deep geological disposal of heat-generating waste permanently provides safety for men and the environment (passive safety)

- Generally, repositories for HLW/SF can be designed, constructed, and operated in different geologic environments,
  - be it salt, clay, or crystalline rock

- Examples exist or at least are well advanced in various countries:
  - for salt: the WIPP in USA
  - for clay: Cigéo at Bure in France
  - for crystalline rock: SF repository at Forsmark in Sweden

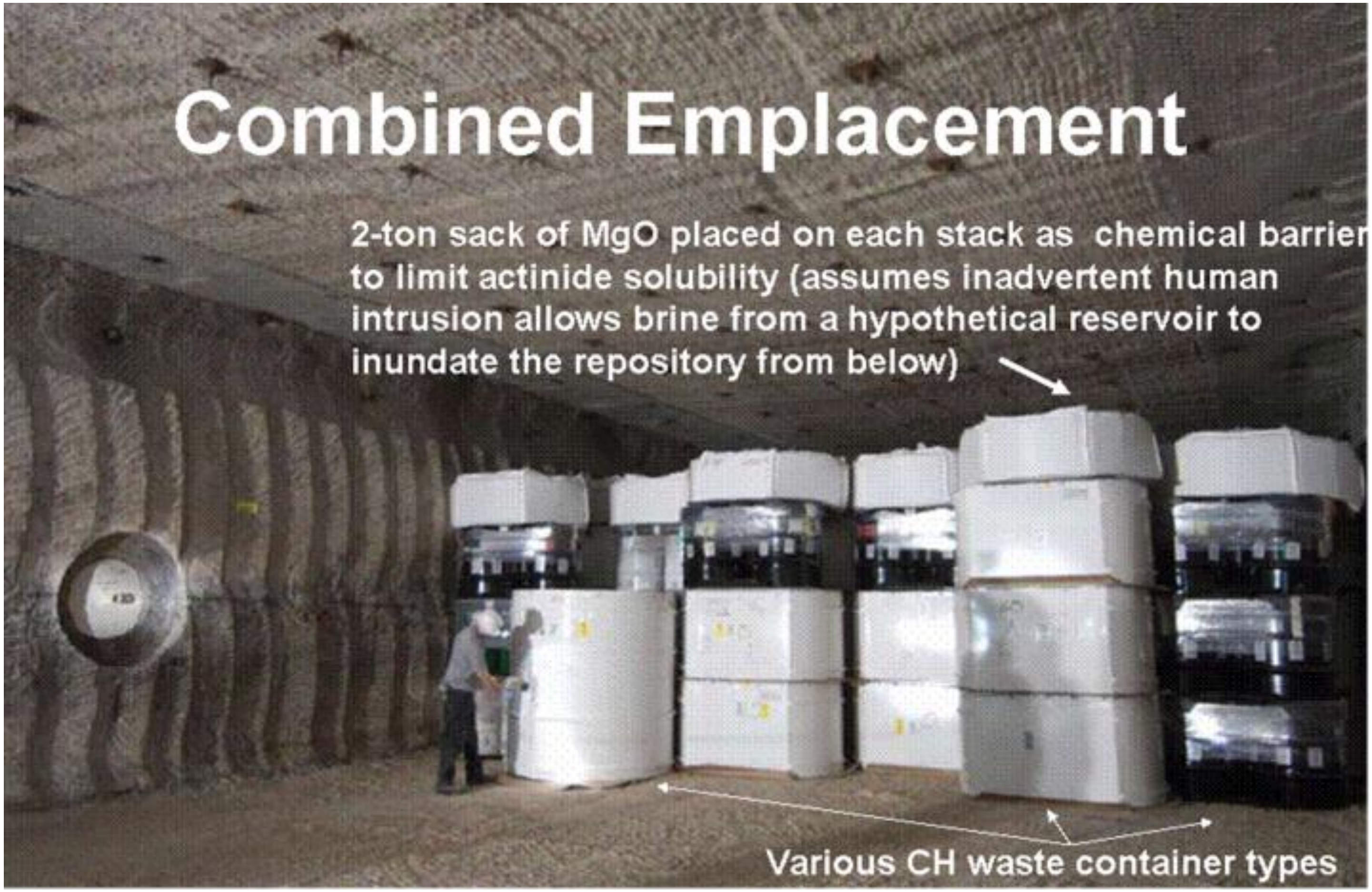
Repository design for WIPP (Waste Isolation Pilot Plant), USA



Project	The U.S. Department of Energy's Waste Isolation Pilot Plant (WIPP)
Location	Southeastern New Mexico in the Chihuahuan Desert
Mission	Safely dispose of U.S. defense-generated transuranic (TRU) waste
Disposal Area	655 m below the surface in 1 000 m thick Permian salt

[Source: N. Rempe, WIPP]

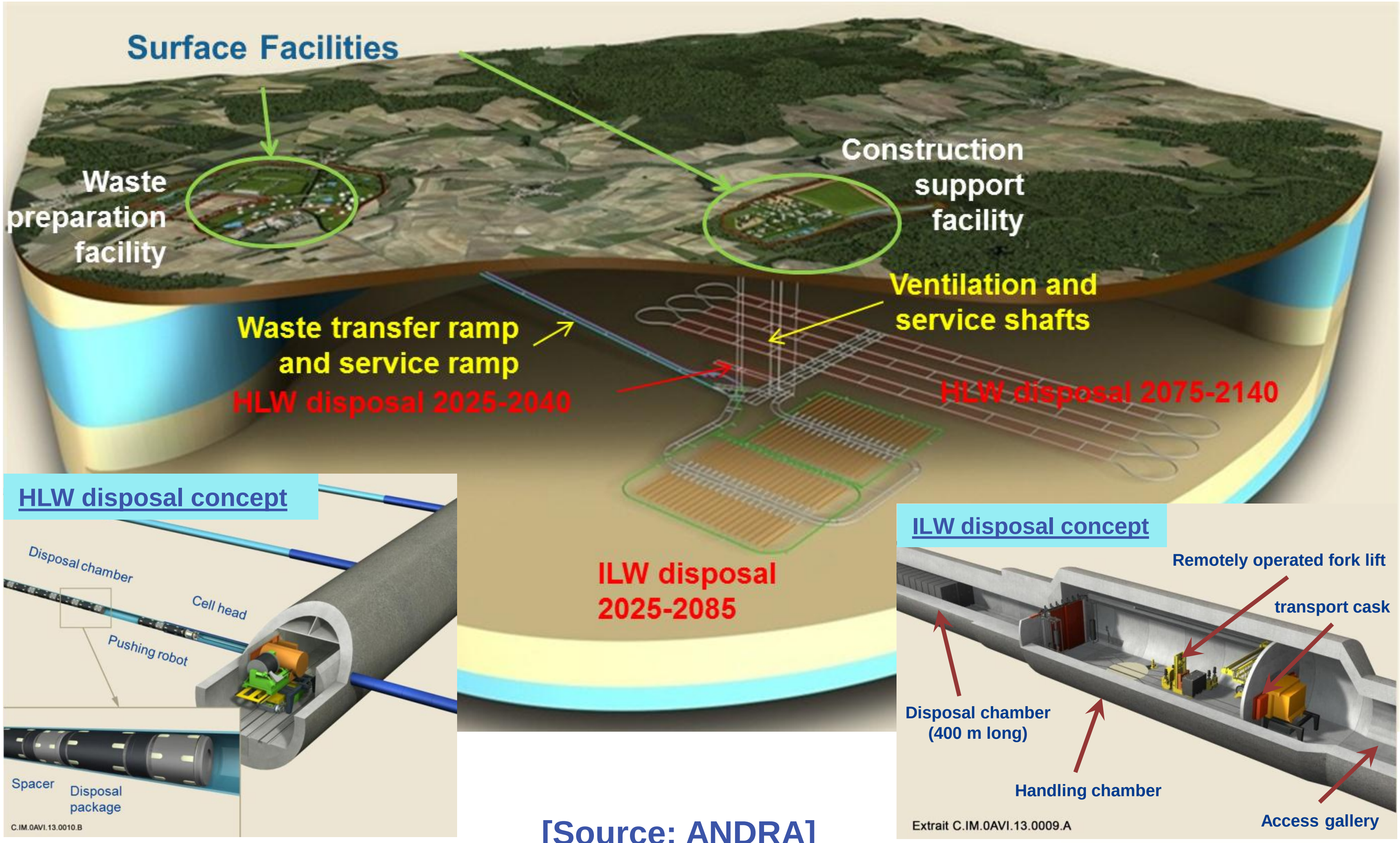
Emplacement of waste containers at WIPP (USA)



[Source: N. Rempe, WIPP]

Example of a Repository in Argillaceous Rock (Clay)

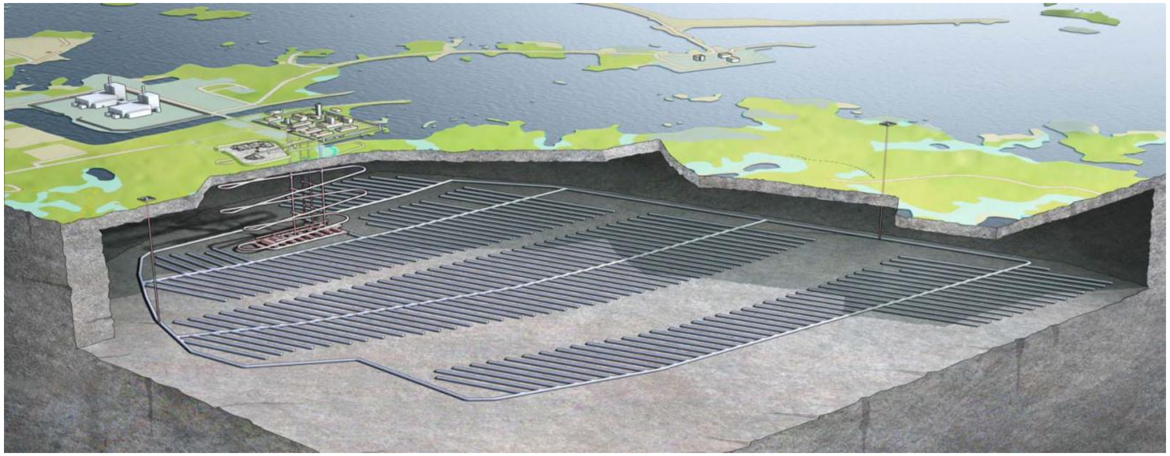
Preliminary design for Cigéo; the French HLW repository project



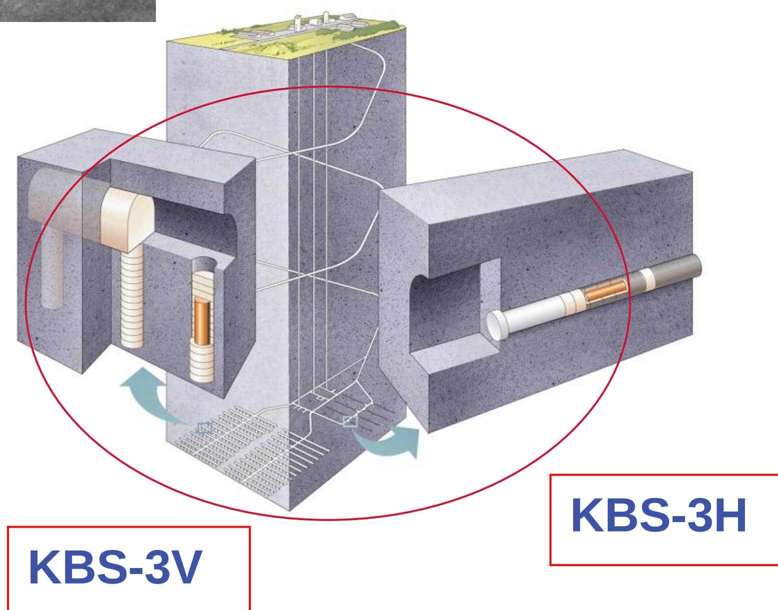
[Source: ANDRA]

Example of a Repository in Crystalline Rock

Preliminary design for the SF repository at Forsmark (Sweden)



Artist impression of the multi-barrier KBS-3 method



[Source: SKB]

Comparison of Repository Systems

- **Challenge:**
  - **How to compare the safety level of potential sites for a HLW repository in different geologic environments?**
  - **What are the implications of the host rock selection on repository design and safety (operating phase and in the long-term)?**

- **Comparison of geologic features at potential repository sites:**
  - **may deliver information with regard to thermal and hydraulic conductivity of the host rock or on other features**
  - **but will not answer the question which site provides the best level of safety**

- **Another approach**
  - **comparison of entire repository systems**

Comparison of Repository Systems

- **Repository system:**

  "The repository system is comprised of the repository mine, the isolating rock zone, and the geological strata surrounding or overlying this rock zone up to surface level, insofar as these are relevant for safety purposes and must therefore be taken into account for the safety case."

  (According to BMU "Safety Requirements Governing the Final Disposal of Heat-Generating Radioactive Waste" as at 30 September 2010 ")

- ***Consequence for a comparison of repository systems:***

  - **Certain knowledge about the repository design has to be made available during each phase of the selection procedure**
  - **A safety and safety demonstration concept adjusted to the repository design and the geologic environment is necessary**

Parameters with Impact on Repository Design

- **Types and amounts of waste (waste package)**
  - ➢ **SF and/or waste from reprocessing**
- **Geologic situation (host rock, surrounding strata, etc.)**
- **Safety concept**
  - ➢ **mainly relying on passive safety (geologic barriers)**
  - ➢ **mainly relying on active safety (technical and geotechnical barriers)**
- **Design temperature at contact waste package and host rock or buffer (<100°C for clay/bentonite, < 200°C for salt)**
- **National/international legislation**
  - ➢ **Safety requirements (BMU, 2010): e.g. retrievability**
  - ➢ **Mining act**
  - ➢ **etc.**

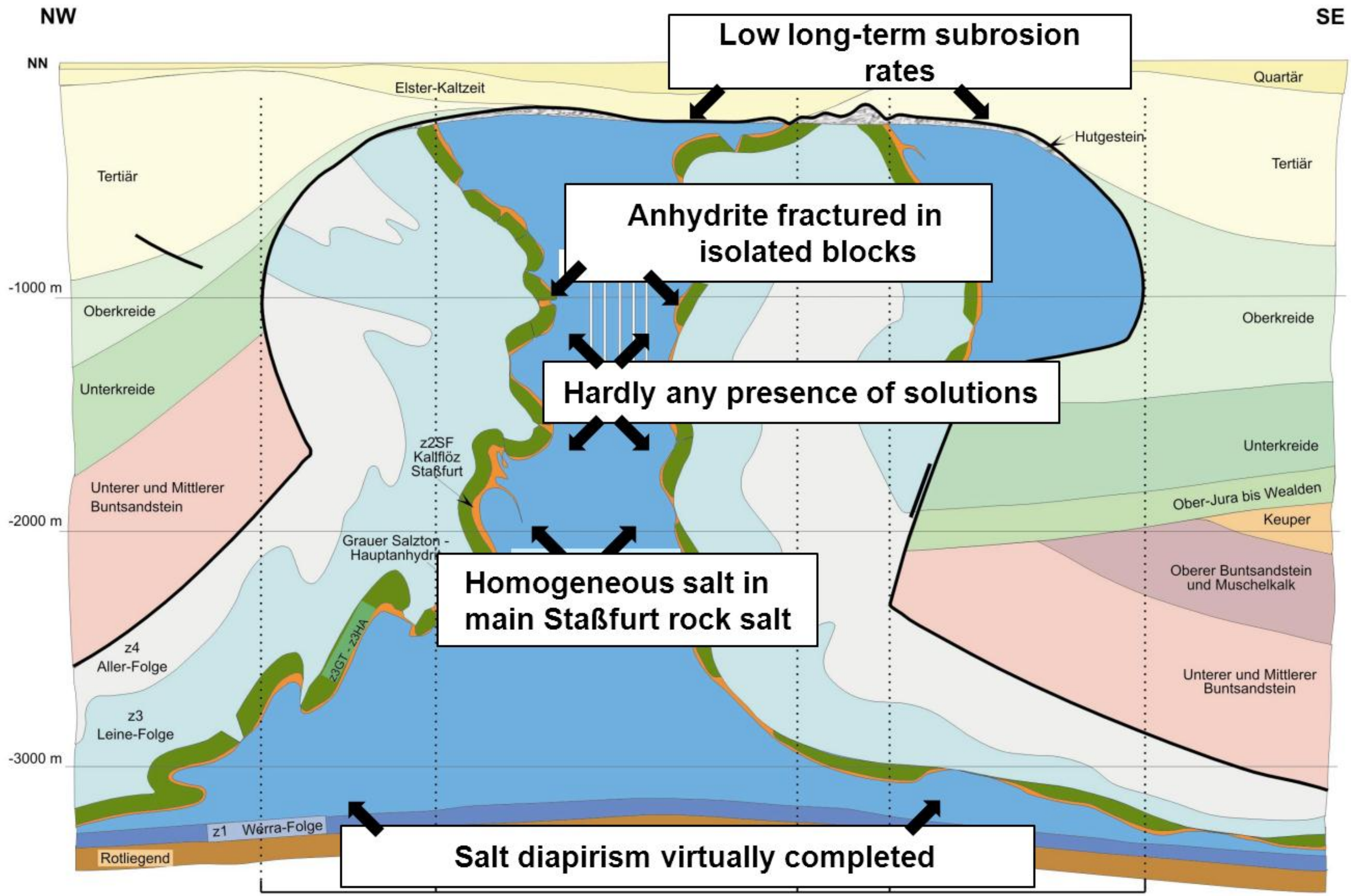
Prospective Waste Quantities (Germany)

Source of Waste			Amounts of Waste			Waste Package	
				SF Elements	tHM	Type	Amount
Spent fuel		PWR	UO_2	12,450 FE	6,415	POLLUX®-10	1,398
			MOX	1,530 FE	765		
		BWR	UO_2	14,350 FE	2,465		520
			MOX	1,250 FE	220		
		WWER-PWR	UO_2	5,050 FE	580		202
		Total	**-**	**-**	**10,445**		**2,120**
Waste from reprocessing	CSD-V	AREVA NC (F)	3,024 Canisters			POLLUX®-9	336
	CSD-V	Sellafield Ltd. (UK)	565 Canisters				63
	CSD-V	VEK (D)	140 Canisters				16
		Total	**3,729 Canisters**				**415**
	CSD-B	AREVA NC (F)	308 Canisters			POLLUX®-9	**35**
	CSD-C	AREVA NC (F)	4,1404 Canisters			POLLUX®-9	**456**
		Total	**8,141 Canisters**				**906**
Spent fuel of prototype and research reactors		AVR	250,000 Fuel Elements (Pebbles)			CASTOR® THTR/AVR	152
		THTR	611,878 Fuel Elements (Pebbles)				305
		KNK II	2,413 Fuel rods from 27 Fuel Elements			CASTOR® KNK	4
		Otto-Hahn	52 Fuel Rods				
		FRM II	approx. 120 - 150 MTR Fuel Elements			CASTOR® MTR 2	30
		BER II	approx. 120 MTR Fuel Elements				20
		Total	**-**			**-**	**511**
Structural components of SF		**Total**	**-**			MOSAIK®	**2,620**

Repository Design (host rock salt)

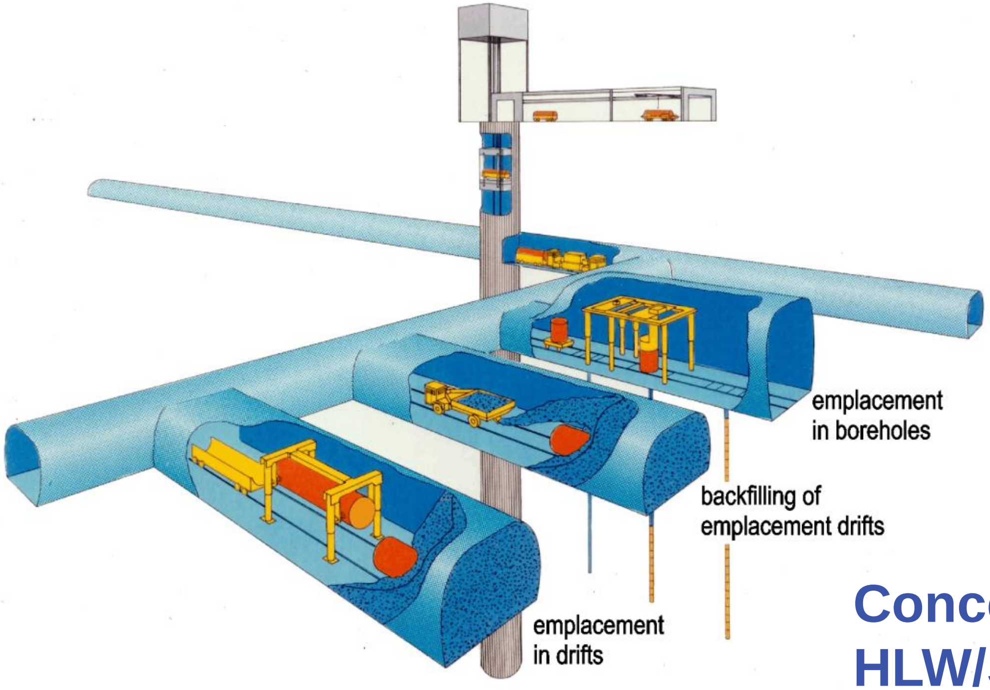
- **The Gorleben salt dome – selected in the late 1970s –**
  - **has been investigated on its suitability to host a repository for spent nuclear fuel and for heat-generating radioactive waste from reprocessing; results are compiled in several reports (BGR)**
  - **a suitable reference repository concept has been developed since**
  - **demonstration tests for the safe and reliable transport and emplacement of waste packages have successfully been carried out**
  - **a preliminary safety analysis (vSG) was completed in spring 2013**

Features of Gorleben Site



[Source: BGR/GRS]

Repository Concept for Heat-Generating Waste

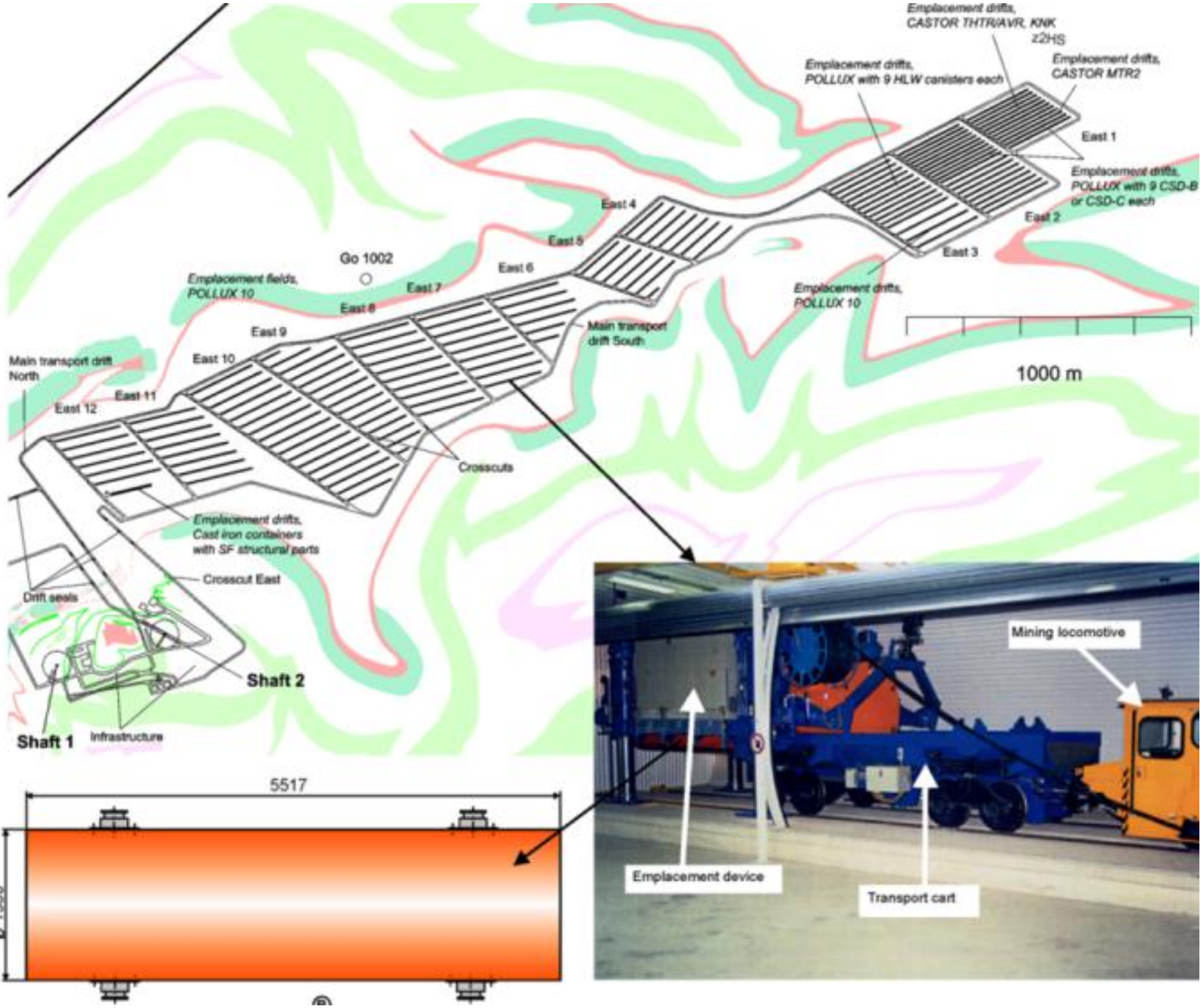


Concept (early 1980s) for a HLW/SF Repository in Rock Salt

- **Deep geological disposal**
  (depth: 800 to 900 m)
- **Emplacement of HLW/SF**
  - either in horizontal drifts
  - or in deep vertical boreholes
- **Backfill material: crushed salt**

Repository Design: Drift Disposal of POLLUX® Casks

site-specific design of repository



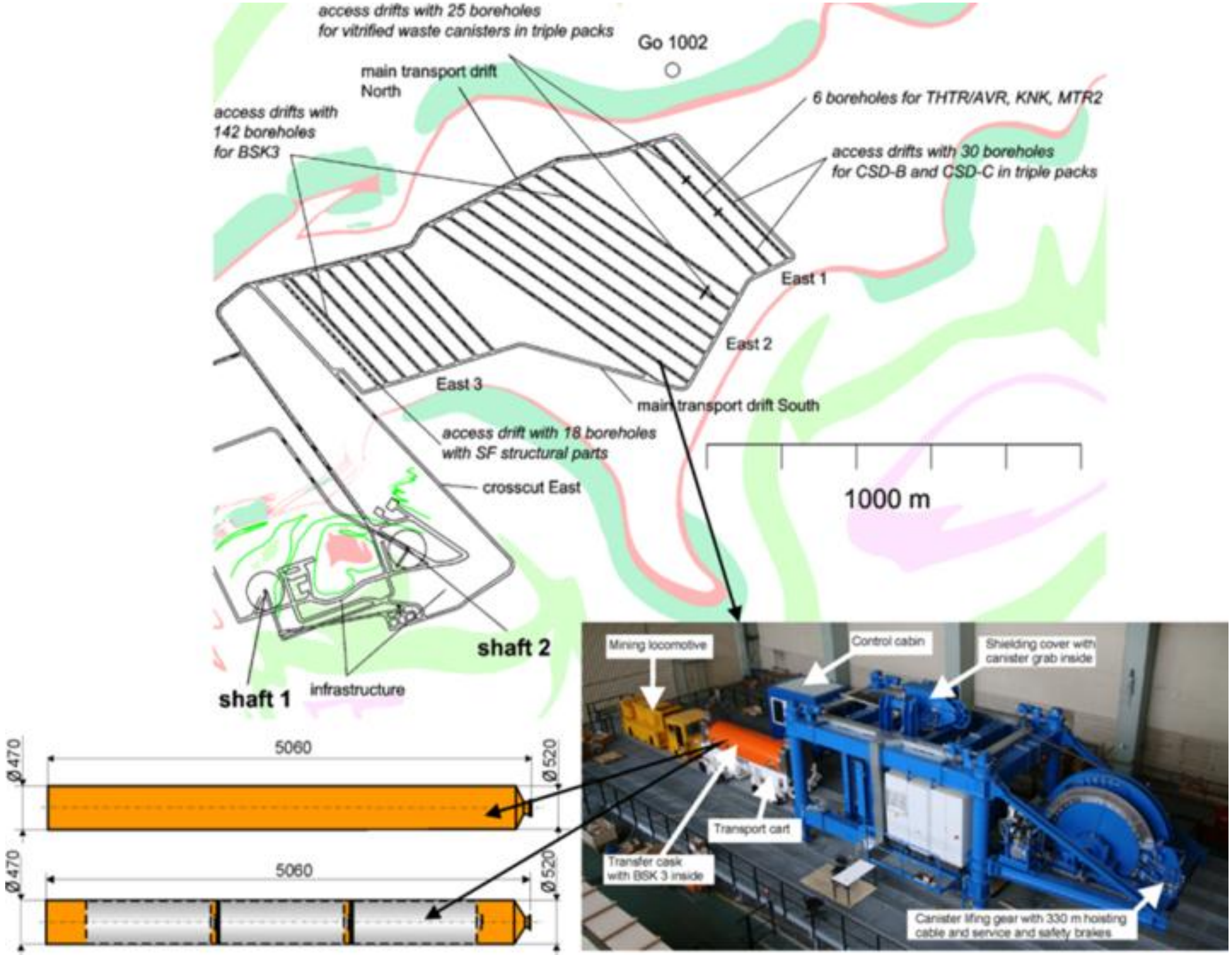
waste package for HLW and SF: POLLUX® cask

cheque of safety and reliability of transport and emplacement technique by means of 1:1 scale demonstration tests

[Source: VSG]

Repository Design: Borehole Disposal of Waste Canisters

site-specific design of repository

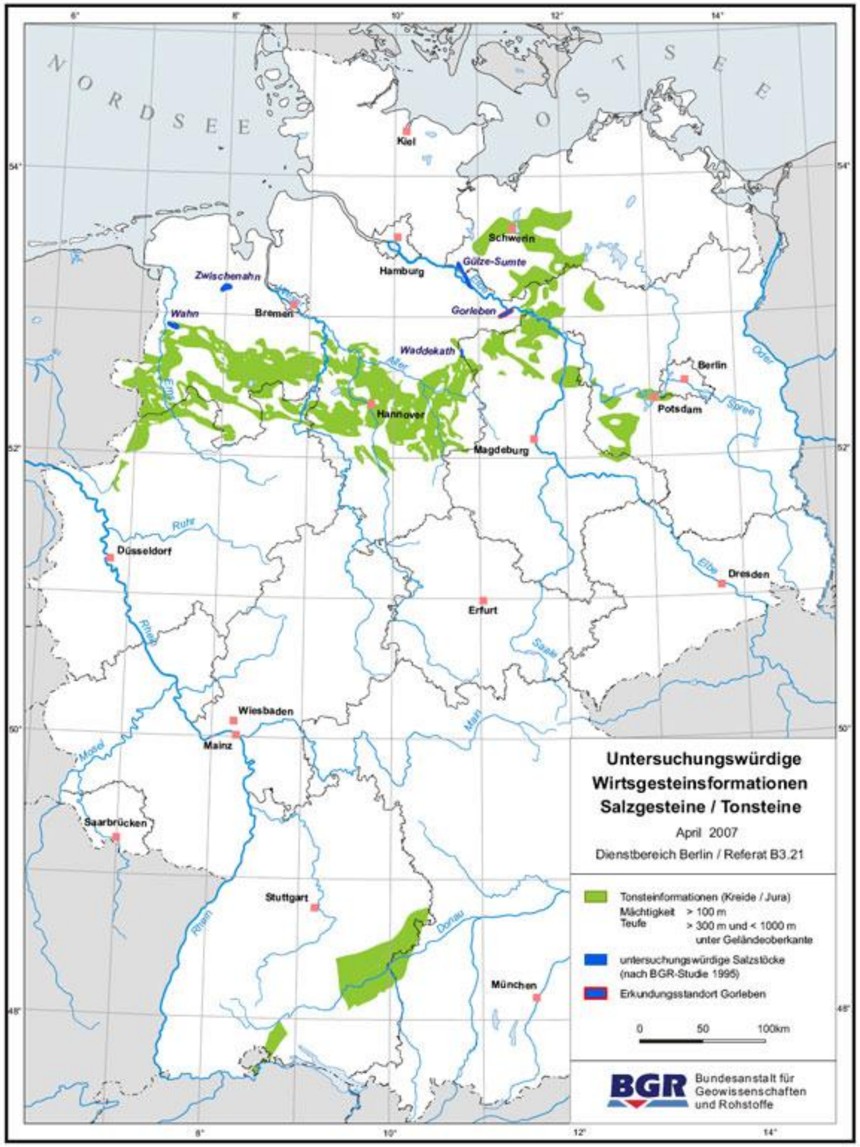


waste package for HLW and SF: BSK 3

cheque of safety and reliability of transport and emplacement technique by means of 1:1 scale demonstration tests

[Source: VSG]

Potential Areas of Rock Salt and Argillaceous Formations (Clay)

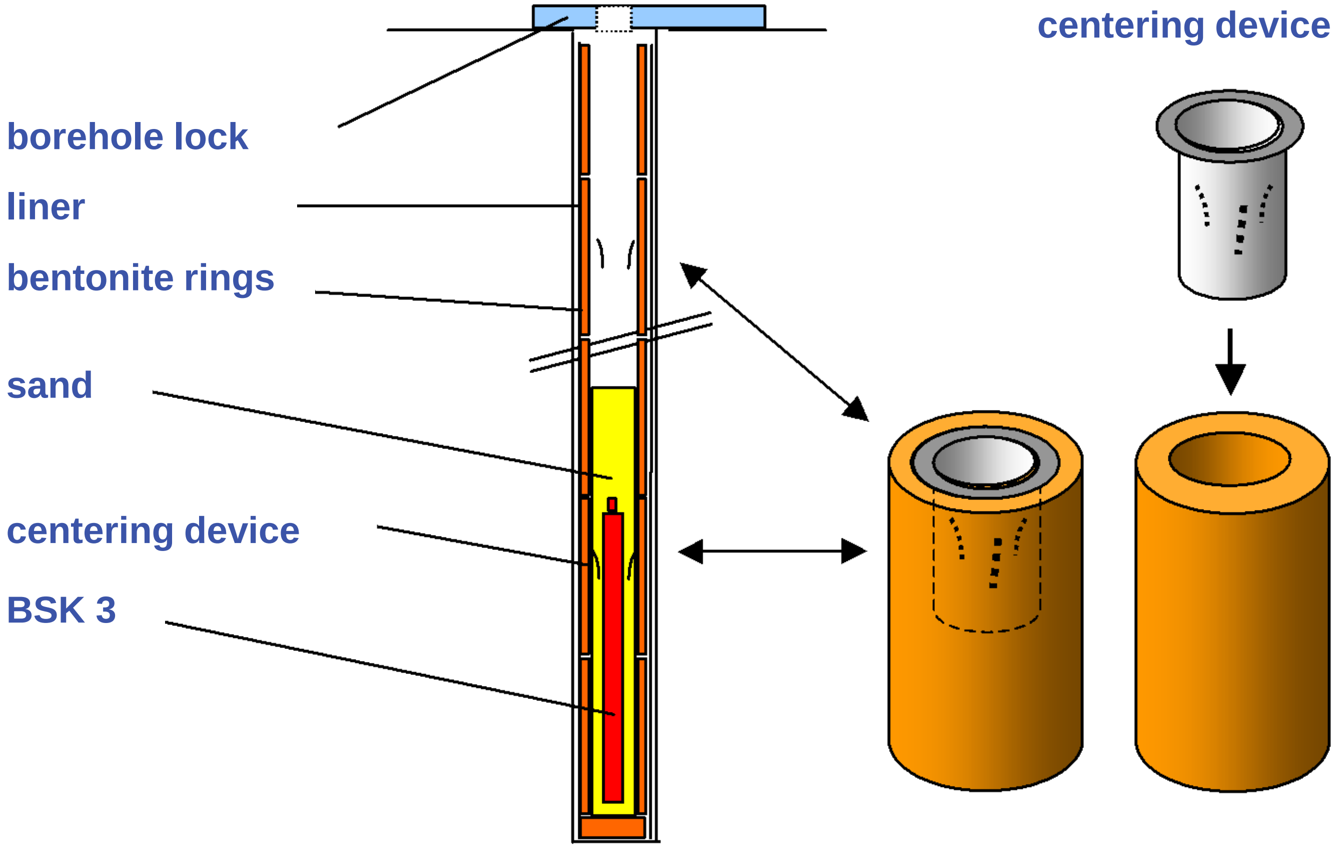


Map of Germany with potential rock salt and argillaceous formations (clay) for a HLW repository

„Because of its unfavorable geologic conditions in comparison to domal salt and to clay formations in Germany crytaline rock formations will not be prefered as host rock for disposal of radioctive waste.“

[Source : BGR]

Selected variant: borehole emplacement concept (BSK)
(developed in the context of R&D project ERATO)



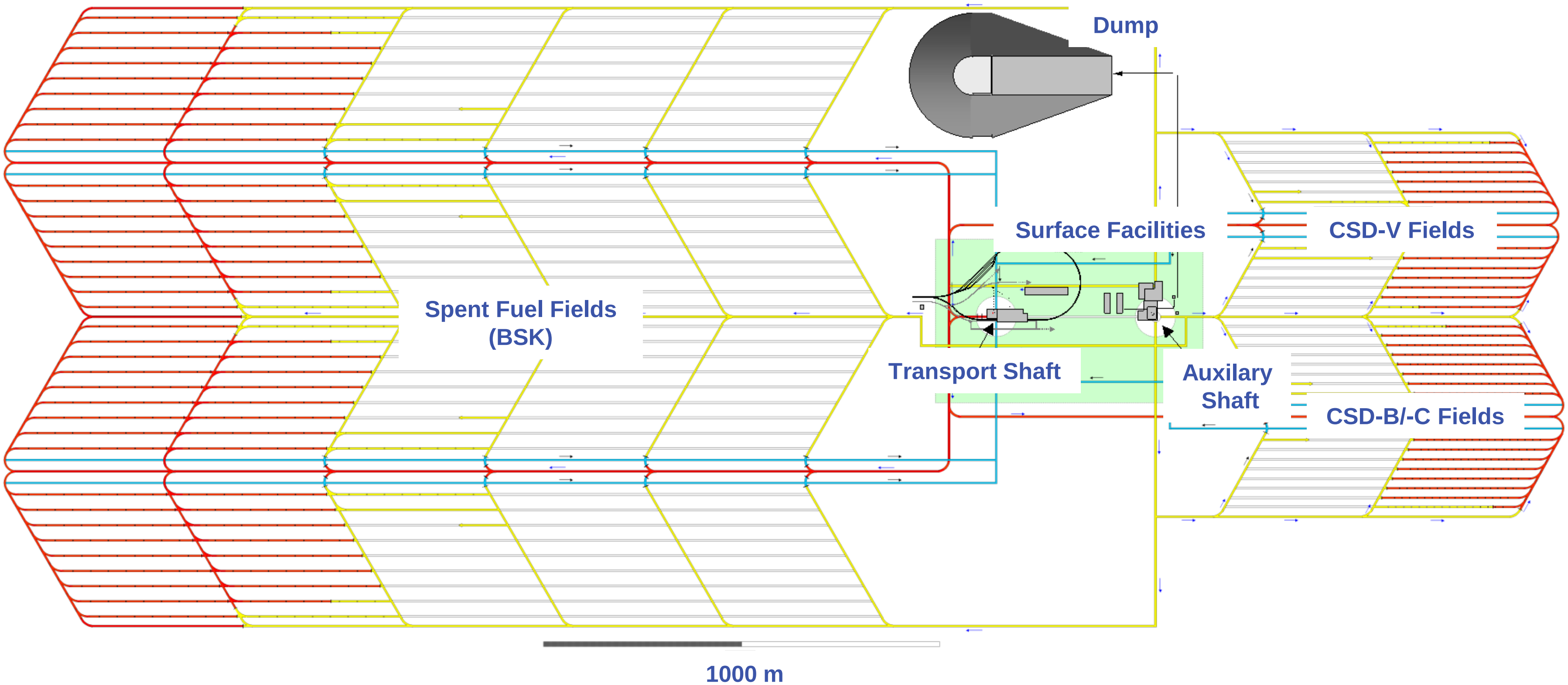
Reason for variant selection (inter alia):

- **minimal repository footprint;**
- **lowest mass for transfer cask (51 tonnes)**

Generic Repository Concept in Argillaceous Rock (Clay)

Repository design – borehole emplacement concept

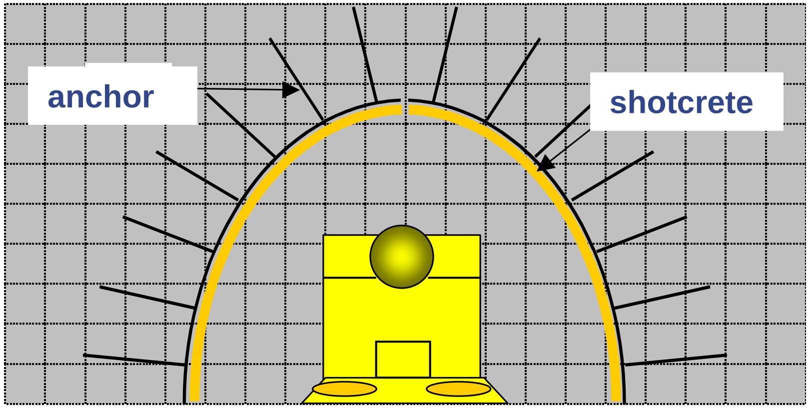
(developed in the context of R&D project ERATO)



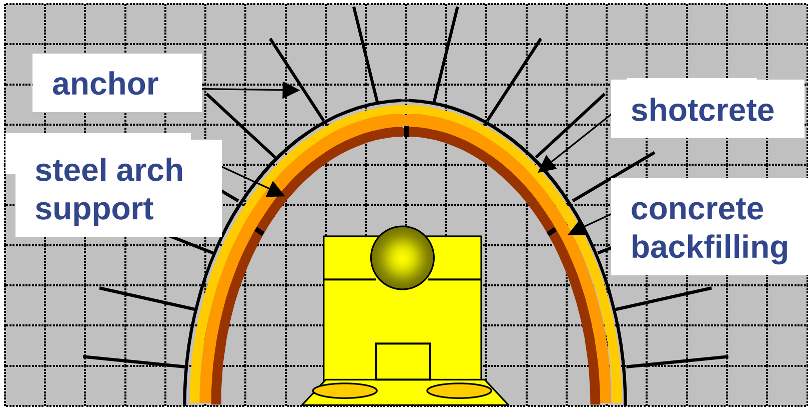
footprint: approx. 3.8 km²;
total length of drifts: approx. 100 km

Technical support of mine openings:

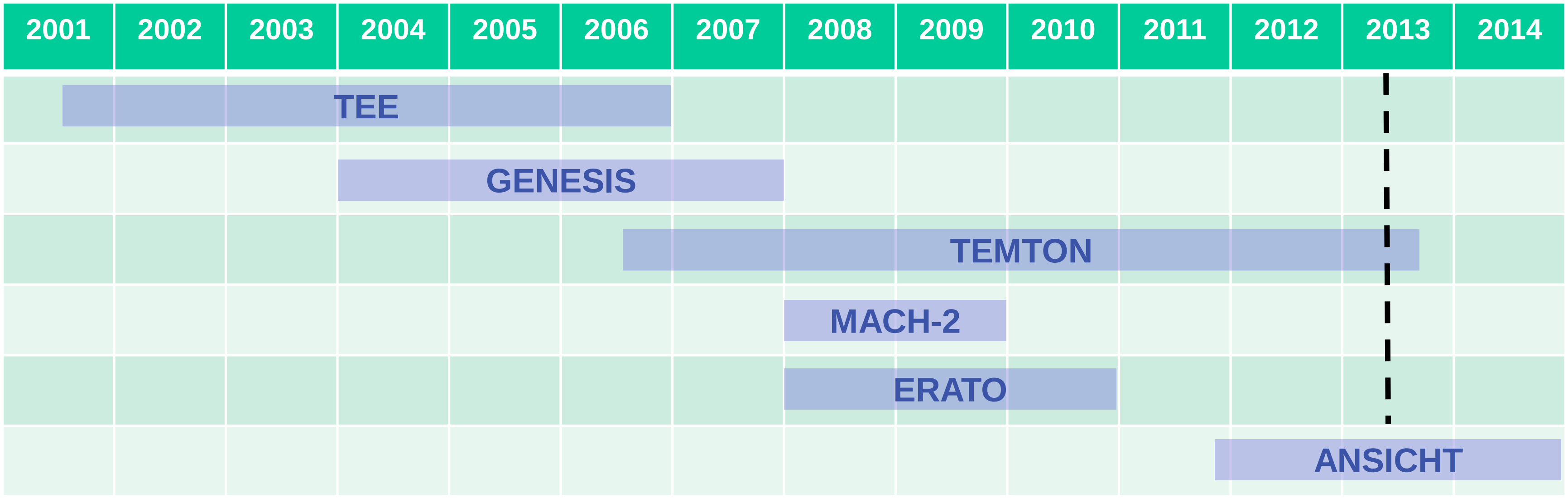
Emplacement drifts: anchor-shotcrete construction



Transport drifts: anchor-shotcrete construction with steel arch support and concrete filling



R&D-Projects for a HLW-Repository in Clay



List of R&D-Projects funded by BMWi:

Acronym	*subject of R&D work*
TEE	REP (Bure), HE-D (Mt. Terri), Lab., THM-Simulation
GENESIS	Repository design at different locations in Germany
TEMTON	TER+TED (Bure), Mine-by (Mt. Terri), Lab., T-load on clay, EDZ, THM-Simulation
MACH-2	THM-Simulation for preparation of Twin-hole Experiment at Mt. Terri)
ERATO	Development of a reference disposal concept in clay in Germany
ANSICHT	Development of a methodology for demonstrating the safe enclosure in clay, Germany

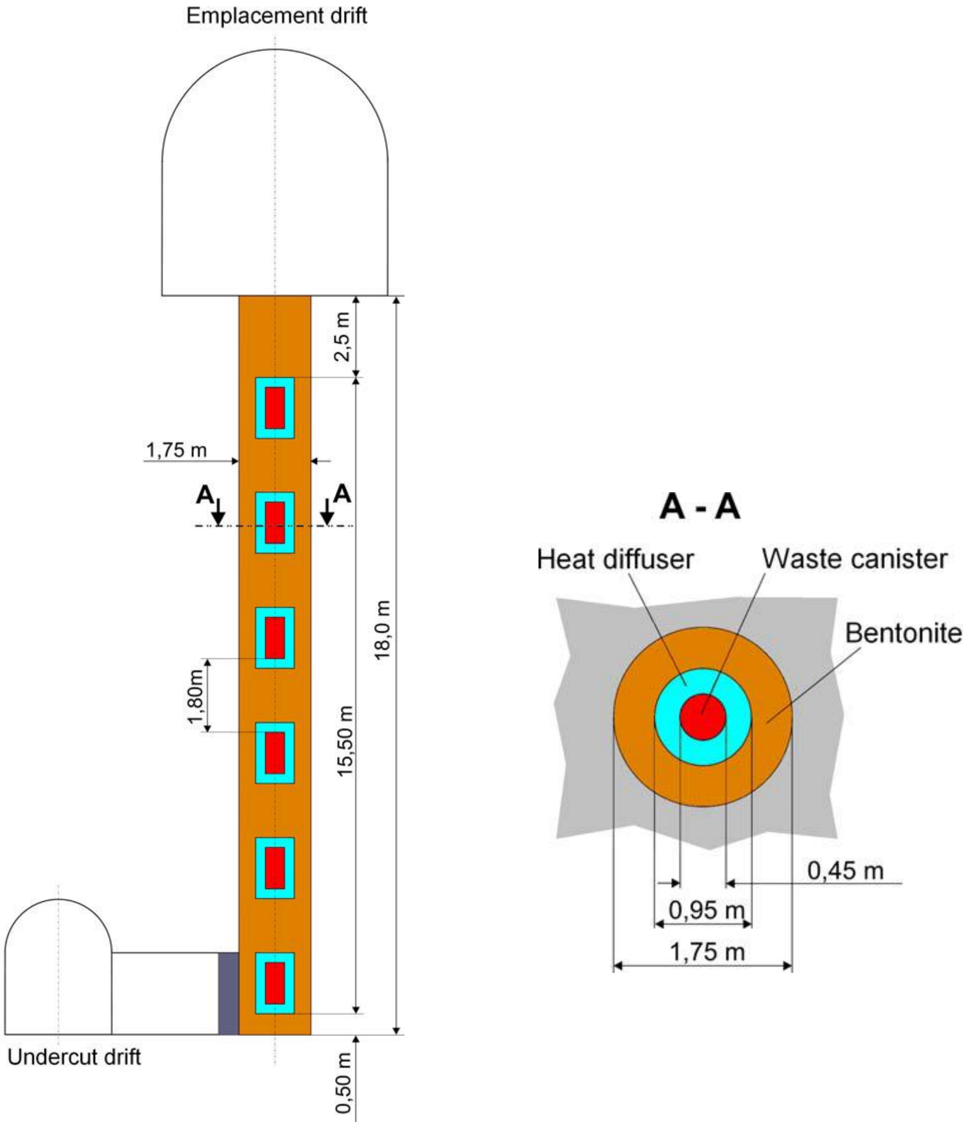
Generic Repository Concept in Crystalline Rock

- **In Germany general knowledge available for HLW repository design in crystalline rock**
  - **gained within the scope of international information exchange**
  - **gained within the scope of international R&D cooperation**

- **Safety concept for a repository in crystalline rock different**
  - **fractures in the host rock may exist**
  - **host rock has insufficient protection capacity against water ingress**
  - **safety function provided by the waste container and/or the geotechnical barriers**

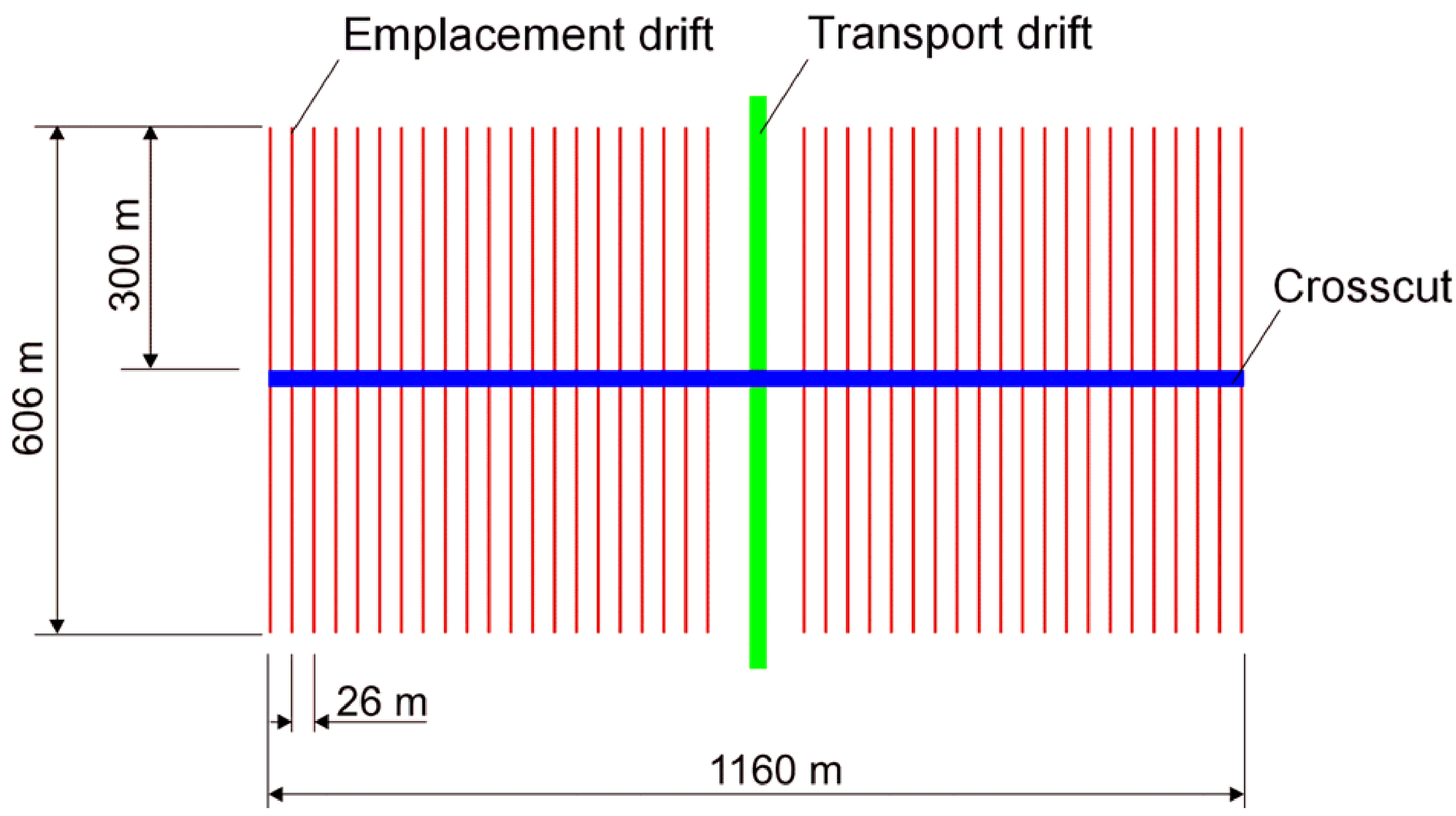
Generic Repository Concept in Crystalline Rock

Preliminary Repository Design: Borehole Disposal of Waste Canisters



[Source: Final report, ASTER project]

Generic design of repository mine



[Source: Final report, ASTER project]

Summary and Conclusions 1/2

1. **Repository designs for the long-term safe disposal of SNF/HLW are available for different host rock formations and are well advanced**

2. **How to compare the safety level of potential sites for a HLW repository in different geologic environments?**

   - **Comparison of entire repository systems recommended:**
     - ✓ repository itself including waste form and waste package and technical and geotechnical barriers
     - ✓ geologic barriers
     - ✓ safety and safety demonstration concept

3. **Main impacts of host rock on repository design and safety:**

   - **Rock Salt:**
     - ✓ creep behavior of host rock will provide safe enclosure of waste package in the long-term
     - ✓ geotechnical barriers (drift and shaft seals) prevent or delay access of solutions to the waste
     - ✓ mine openings do not require technical support
     - ✓ less and simple maintenance required

Summary and Conclusions 2/2

- **Main impacts of host rock on repository design and safety:**
  - **Argillaceous Rock (Clay):**
    - ✓ creep behavior of host rock may provide safe enclosure of waste package in the long-term (depending on type of clay)
    - ✓ geotechnical barriers (like drift and shaft seals) prevent or delay access of solutions to the waste
    - ✓ geochemical interaction of geotechnical barriers with host rock
    - ✓ mine openings require strong technical support (steel liner and/ or concrete walls)
    - ✓ maintenance of technical support constructions required
  - **Crystalline Rock:**
    - ✓ host rock cannot provide safe enclosure of waste package
    - ✓ technical barriers (waste package) to provide safe enclosure in the long-term
    - ✓ mine openings do not require any technical support
    - ✓ geotechnical barriers (bentonite buffer and shaft seals) prevent or delay access of solutions to the waste

Thank You
for Your Attention!