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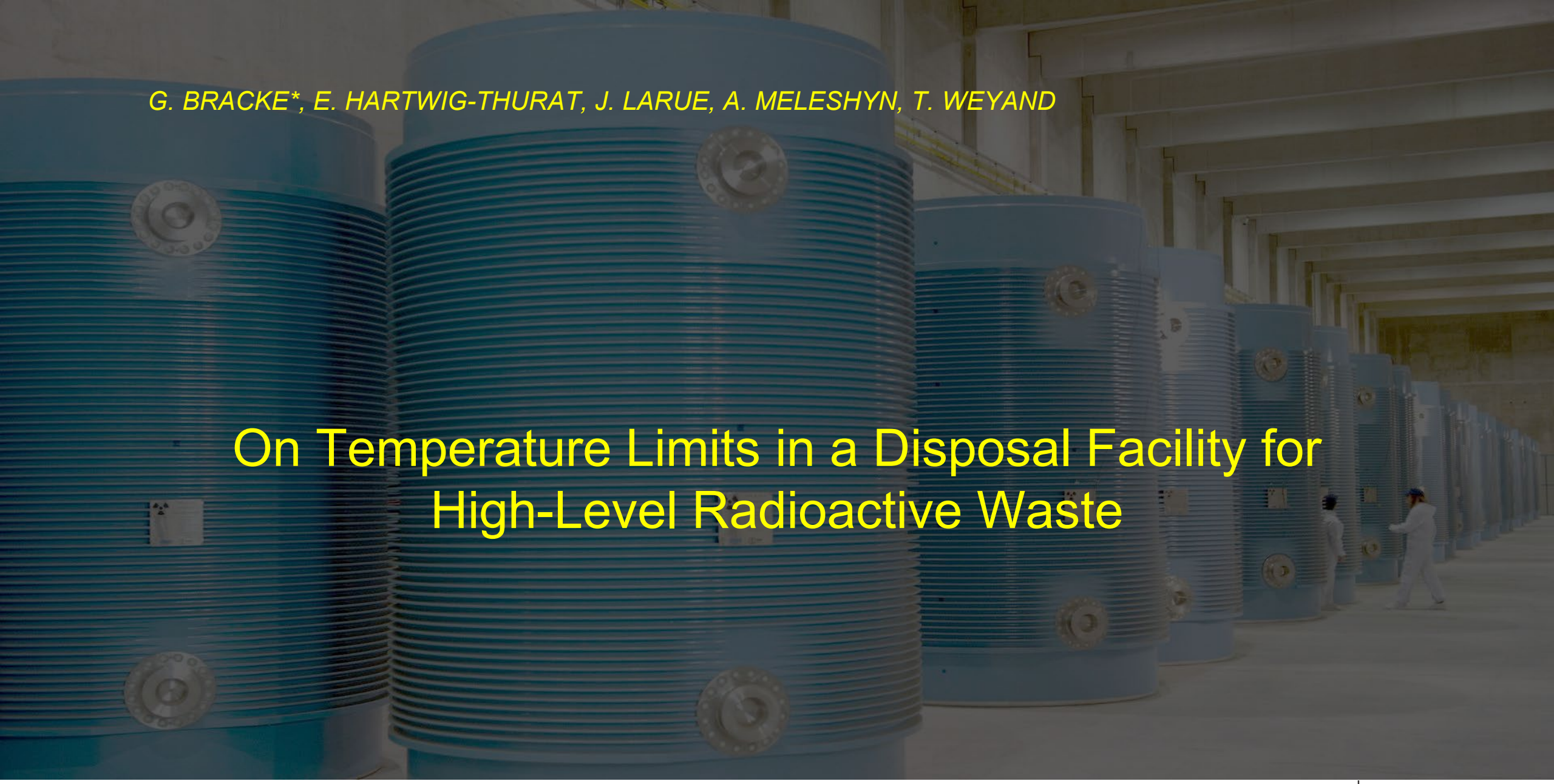
On Temperature Limits in a Disposal Facility for High-Level Radioactive Waste

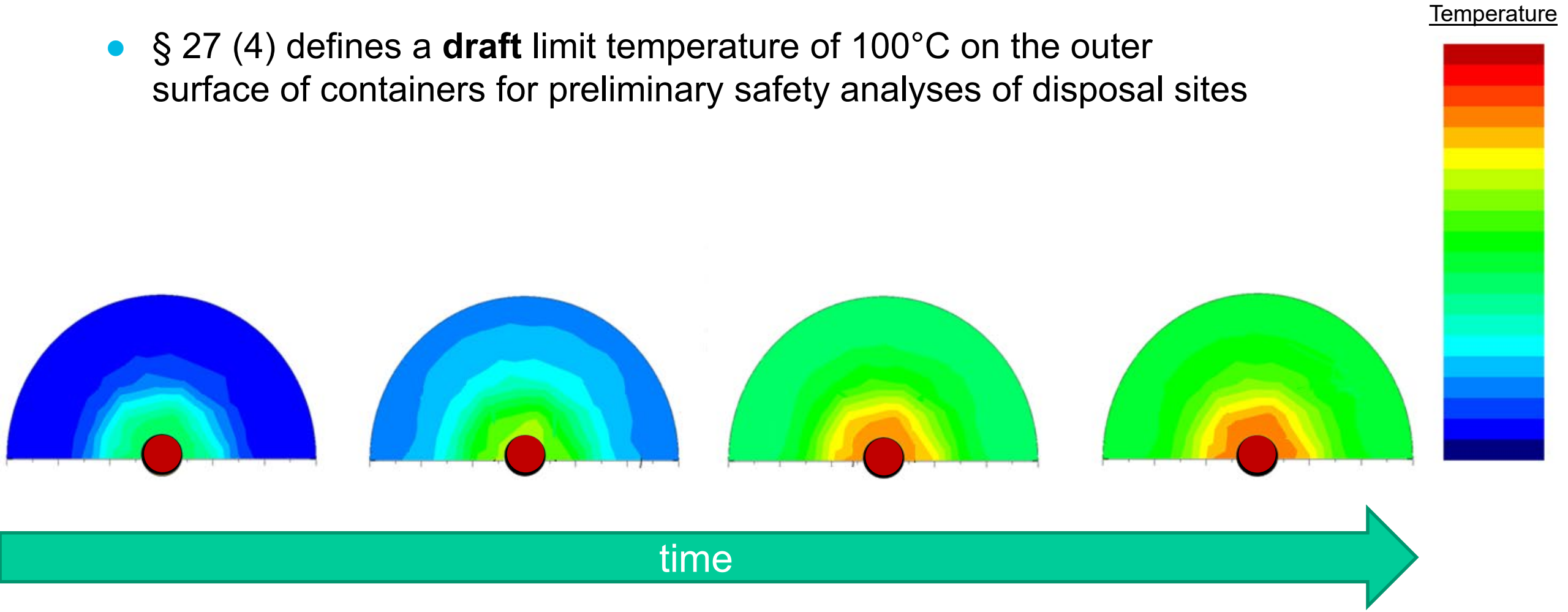


GRS

EUROSAFE 2019

Site selection act (2017)

- § 27 (4) defines a **draft** limit temperature of 100°C on the outer surface of containers for preliminary safety analyses of disposal sites



Comments, critics

- Temperatures below 100°C are not necessarily advantageous for safety
- Potential sites may be excluded
- Large impact on the development of concepts

Objective

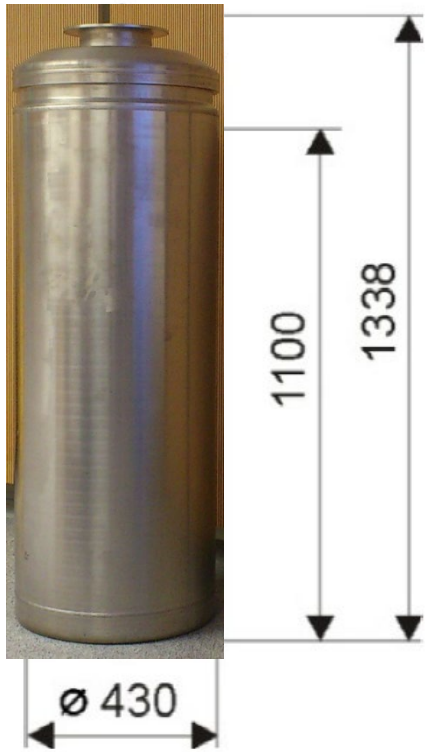
- Presentation and discussion of some THCMB processes, which are temperature dependent

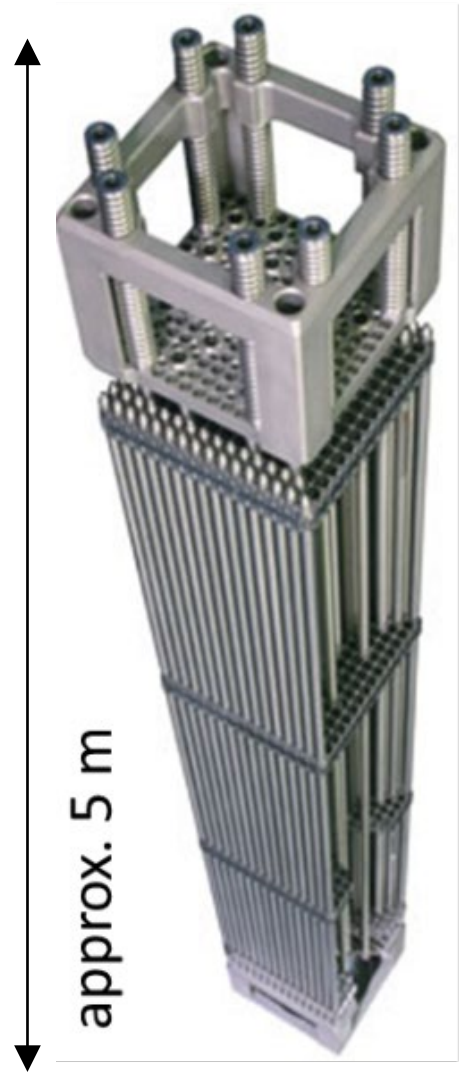
- Consideration in concepts ?

- How to assign temperature limits ?

High-level radioactive waste in Germany

- Spent fuel elements (35000 pieces, 10500 Mg - 7600 m^3 as fuel rods)
- Vitrified waste (8000 pieces, 2000 m^3)
- Spent fuel pebbles (2000 m^3)

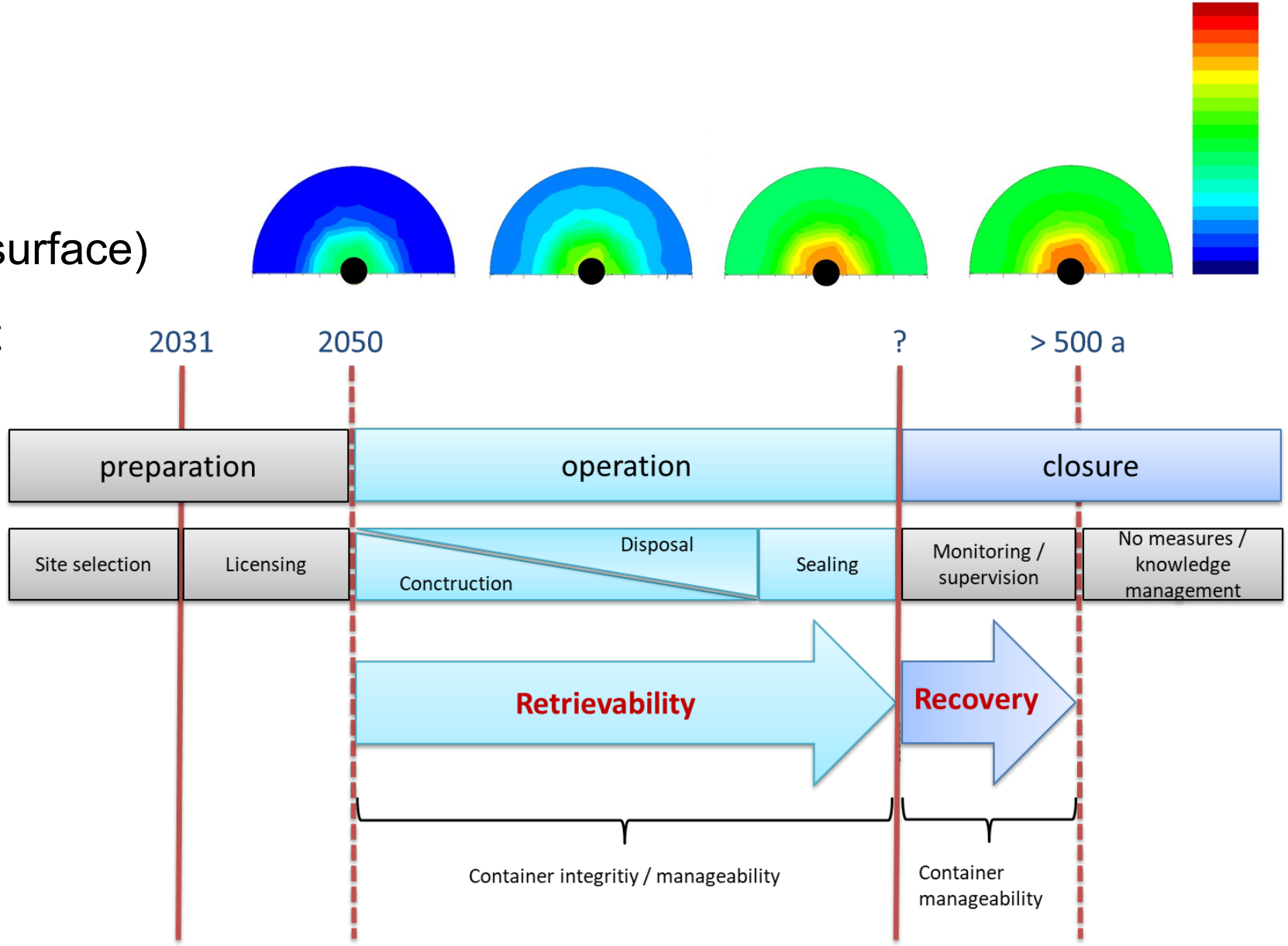




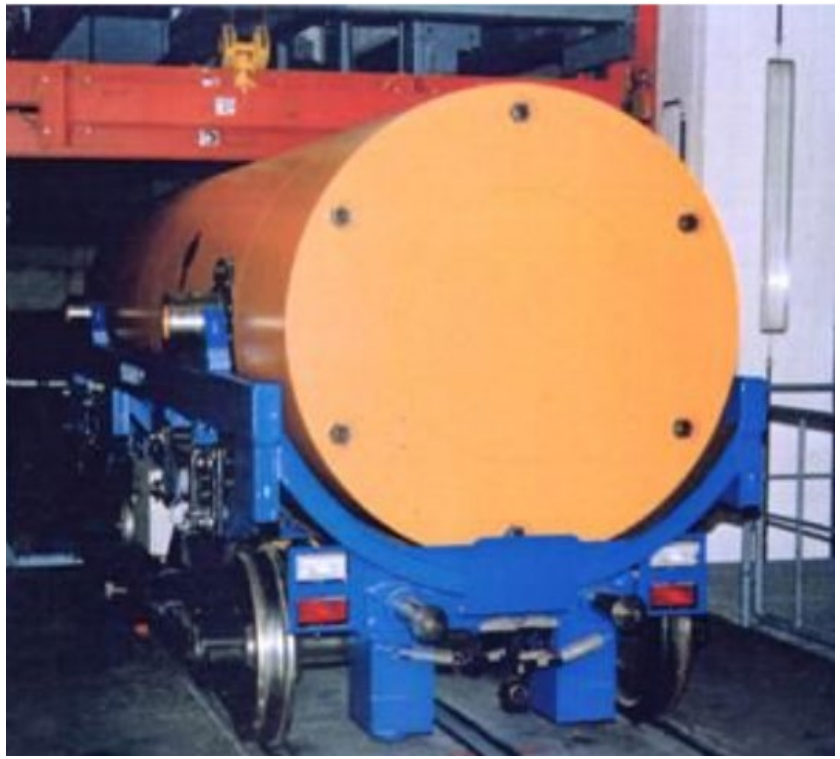
Definitions

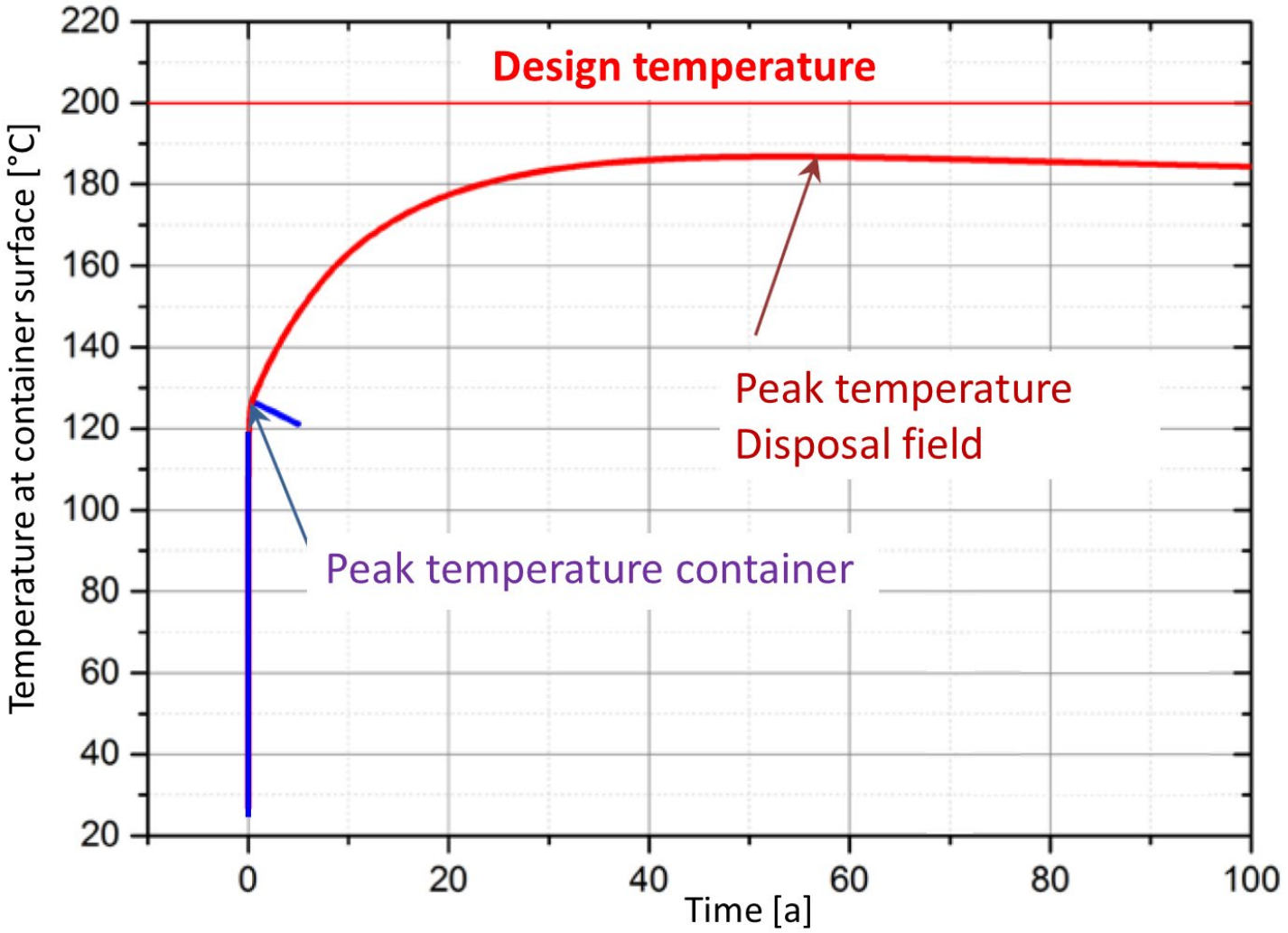
- **Draft** temperature limit (surface)
- **Design** temperature limit
- Temperature field
- Components

- Retrievability / Recovery



Temperatures of a disposed POLLUX container





Disposal concepts and temperature

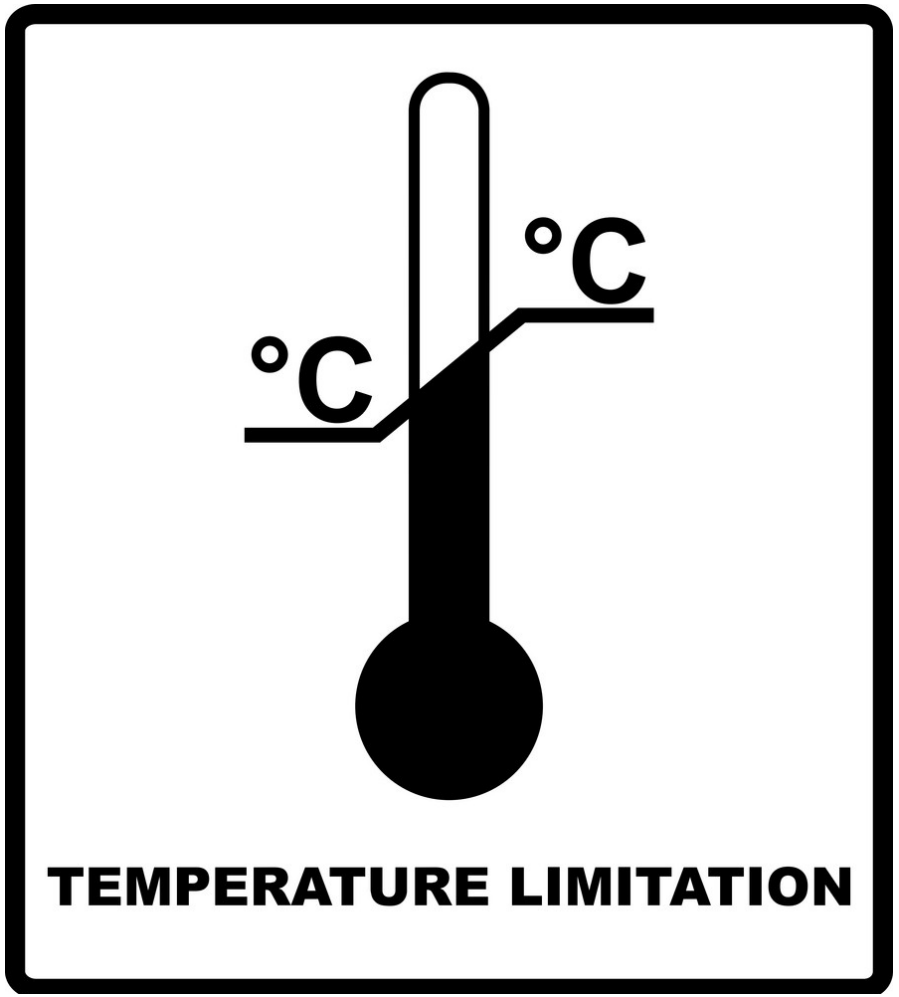
	Unit	Rock salt	Rock salt	Clay rock	Crystalline rock
Temperature limit	**°C**	**200**	**100**	**100**	**100**
Minimum disposal area for containers	km²	0.80	1.63	4.87	2.21
Minimum disposal area applying safety distance	km²	0.23	0.40	1.08	1.03
Minimum area for infrastructure facility	km²	0.25	0.25	0.63	0.32
Total disposal area	**km²**	**1.28**	**2.28**	**6.58**	**3.56**

Are there any national regulations on temperature limits elsewhere ?

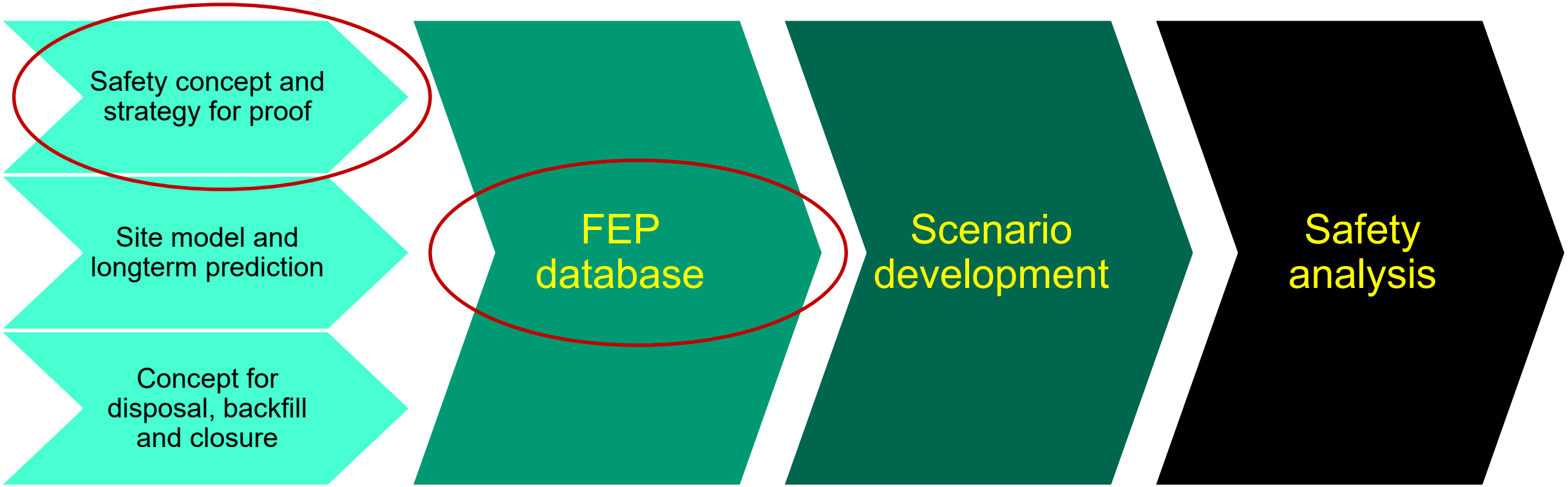
- **No** temperature limits were found in other regulations

However:

- Some general requirements on design temperatures !



Building blocks for a safety analysis



THMCB-Processes in FEP-Catalogues (Features, Events and Processes)

- **Temperature**
  (e.g. structural changes due to illitization, mineral composition, sorption capacity),
- **Hydraulics**
  (e.g. viscosity, density and surface tension; relative permeability of the water phase),
- **Mechanics**
  (e.g. strength properties; cracking due to drying out; swelling capability),
- **Chemistry**
  (e.g. diffusive transport; cation exchange; pH value, reactions)
- **Biology**
  (e.g. growth rate of microbes, population of microbes)

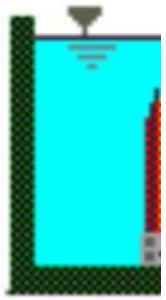
Examples

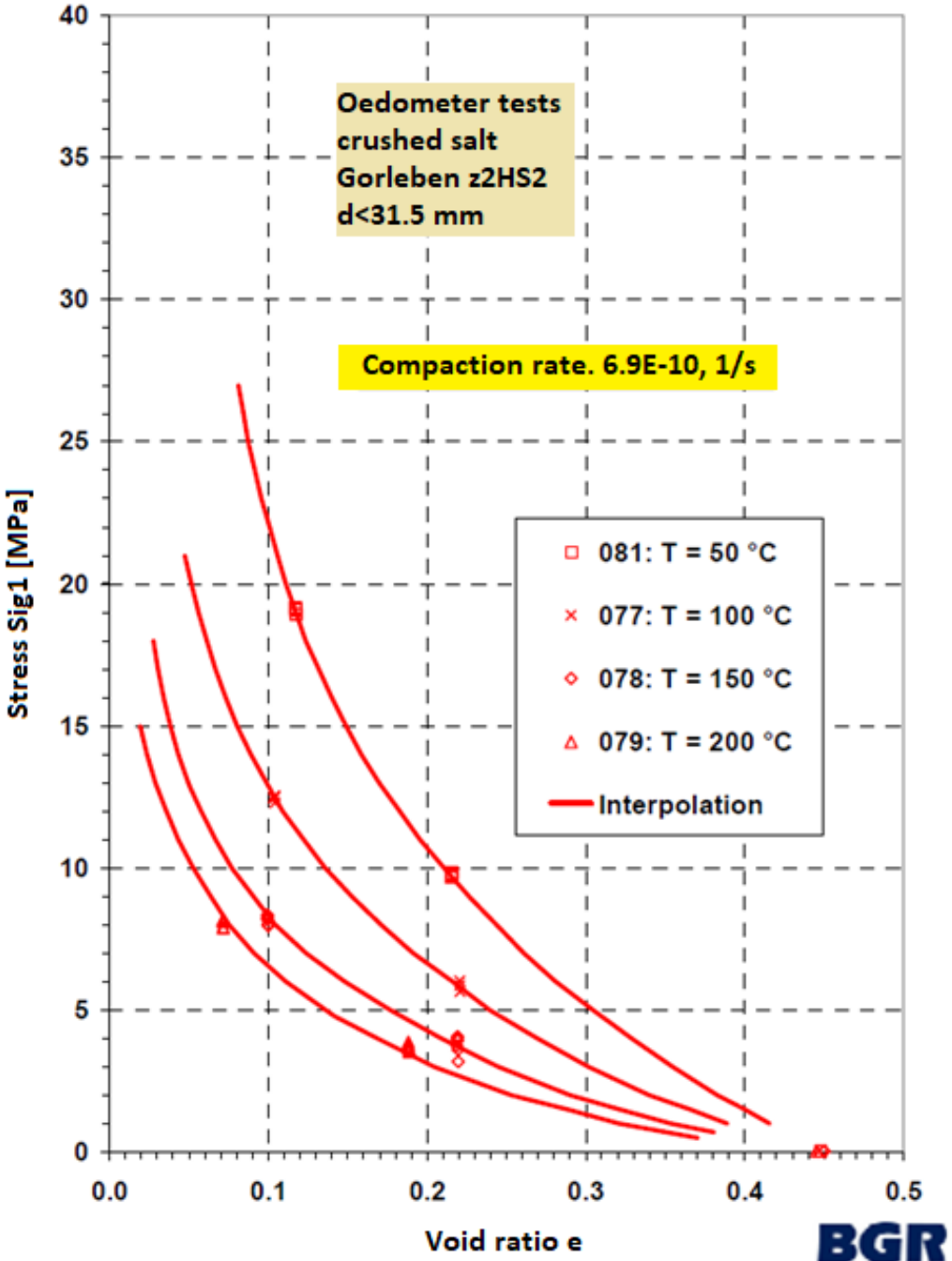
Oedometer tests (crushed salt)

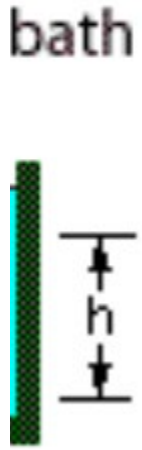
- Stress versus void ratio (porosity)
- Constant compaction rate
- Different temperatures

⇒ **Lower** porosity at **lower** stress with **higher** temperature

⇒ **Higher temperature: Positive effect !**



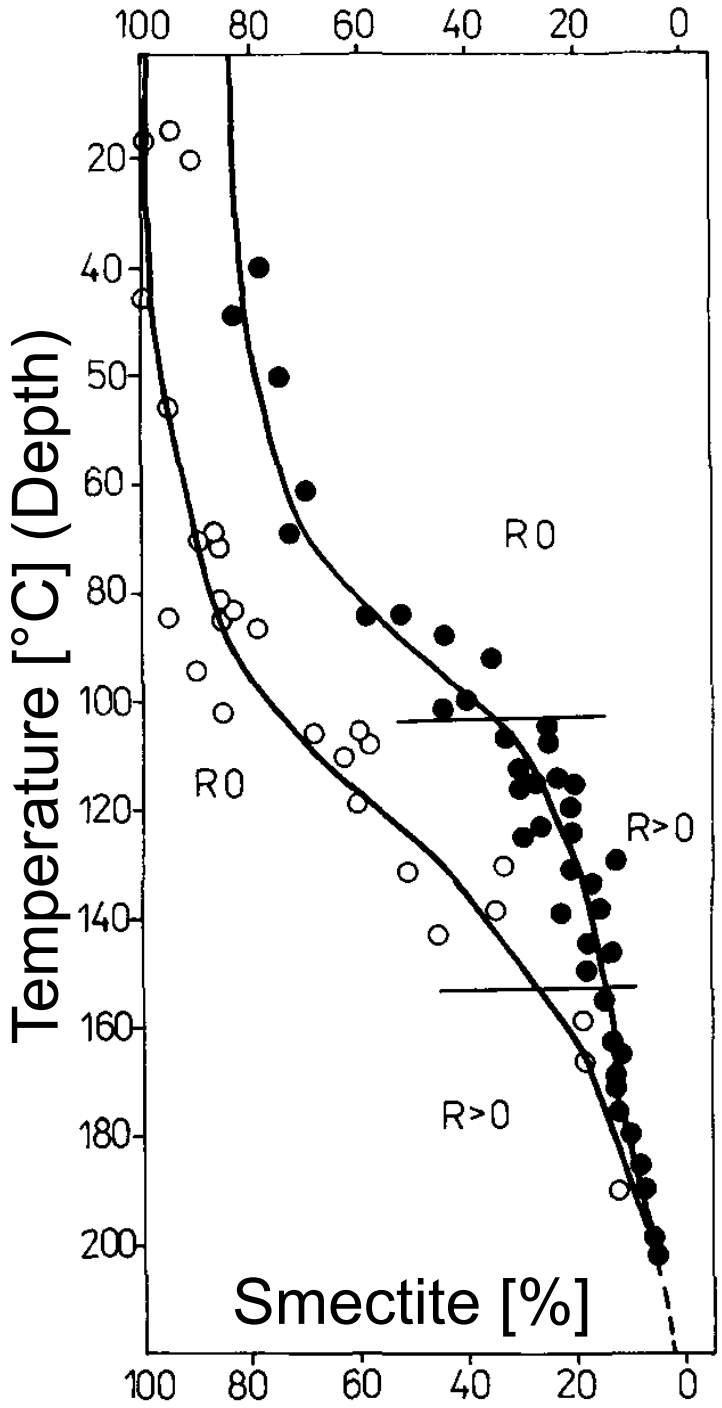




Illite-smectite reaction

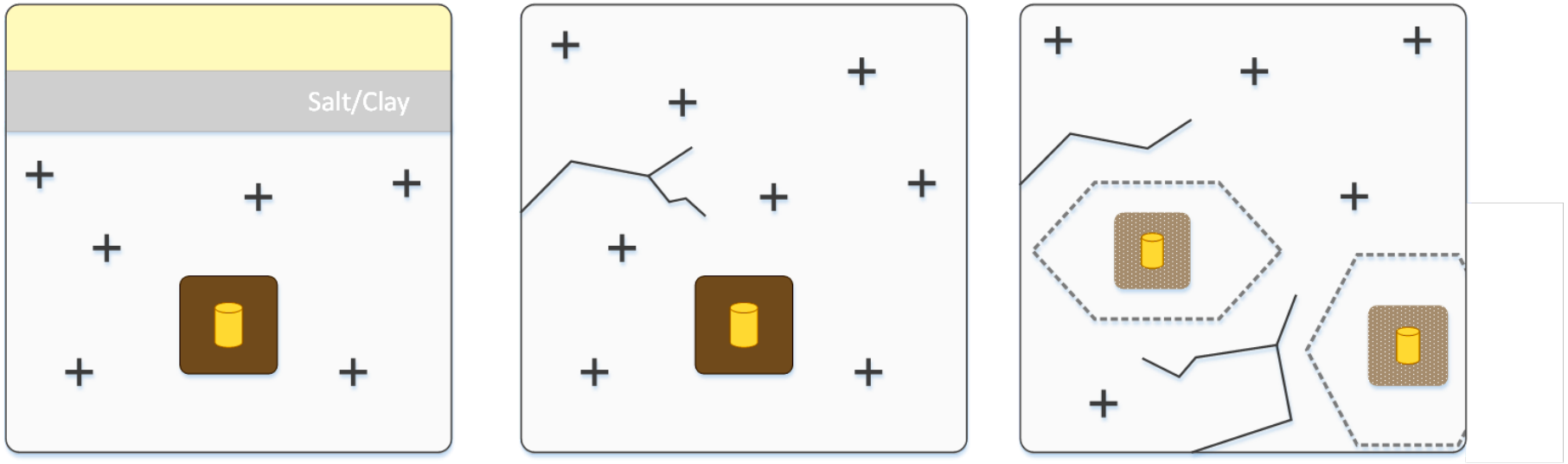
- Smectite content vs. temperature
- Bentonite rich clay (○) and other clay rock / shale (●)
- Reaction starts at approx. 60°C
- Clay rock / shale losts smectite at approx. 100-120°C
- Difference is neglible at approx 150°C
- Other site specific effects must be assessed
- Lower smectite content with higher temperature

⇒ **Higher temperature: Negative effect !**



Fracture fillings (crystalline rock)

- Rock: High temperatures in history ⇒ low impact by temperature increase
- Rock: Thermal conductivity and capacity to be considered
- However: materials, geotechnical barriers and fissure fillings (e.g. hydrothermal alterations) may be safety relevant



Overlying CPRZ | KBS-3 Concept | multiple CPRZ

THMCB processes

- Many temperature-dependent processes
- Safety relevance has to be assessed, however, this is depending on the concept
- Almost all conceivable temperature-dependent processes are listed in FEP catalogues

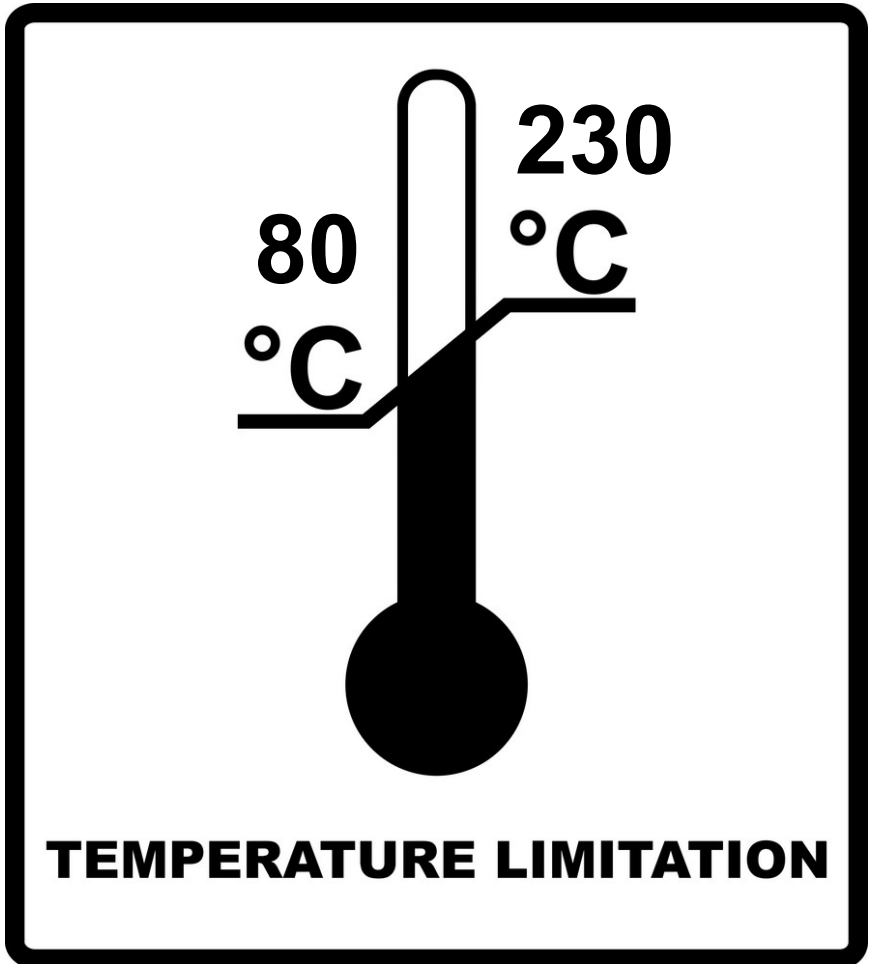
- When fracture fillings in crystalline rock are considered as a barrier, related processes must be evaluated in more detail.

Concepts and Temperatures

- **Design temperature**
  Selected for design and optimization of the geological disposal facility

- **Draft temperature limit**
  Assumption for **preliminary** safety analyses at **the outer surface** of disposed containers

- **Known safety and repository concepts**
  Applied design temperatures for the surface of containers range between 80 bis 230 °C



Summary

- Concepts using clay-based materials
  ⇒ mostly ~100 °C as **design** temperature limit (container surface)
- However, the swiss concept considers a **design** temperature range of 80 – 150 °C on the container surface

- Concepts in rock salt and tuff apply **design** temperature limits of 200 rsp. 230 °C on the container surface
- Based on properties of the rock minerals, water content, …

Summary and conclusion

- **Relevance** of temperature dependent processes is related to the **safety and disposal concept**.
- Typical **design** temperatures - related to the outer surface of the containers and used for design of a disposal facility - are in the range of 80 to 230 °C.
- Derivation of **resilient temperature limits** for the outer surface of containers should be based on (preliminary) safety and disposal concepts.
- **Draft** „temperature limits" may hamper the development of safety and disposal concepts (e. g. optimization of concepts and containment of disposal systems and study of alternative disposal concepts).
- When a safety concept is set and a disposal concept is approved, "*temperature limits*" can be derived, which are well **justified**.

Recommendation

Final “***temperature limits***“ should be set after developing safety and disposal concepts.

1. Development of safety concepts and preliminary disposal concepts
2. Preliminary safety analyses to optimize concepts and design temperatures
3. Derive resilient and specific “*temperature limits*”.

Outlook

- Investigation of temperature evolution and its effects **within** the containers after disposal.

- Evidence for **sufficient manageability** of containers, which have experienced high(er) temperatures externally and internally in the long term, has not been found in this literature review $\Rightarrow$ Improvement

However:

- Expert opinion: Retrieval and recovery is possible

Thank you for your attention

- Any questions ?

(But not about climate change !)