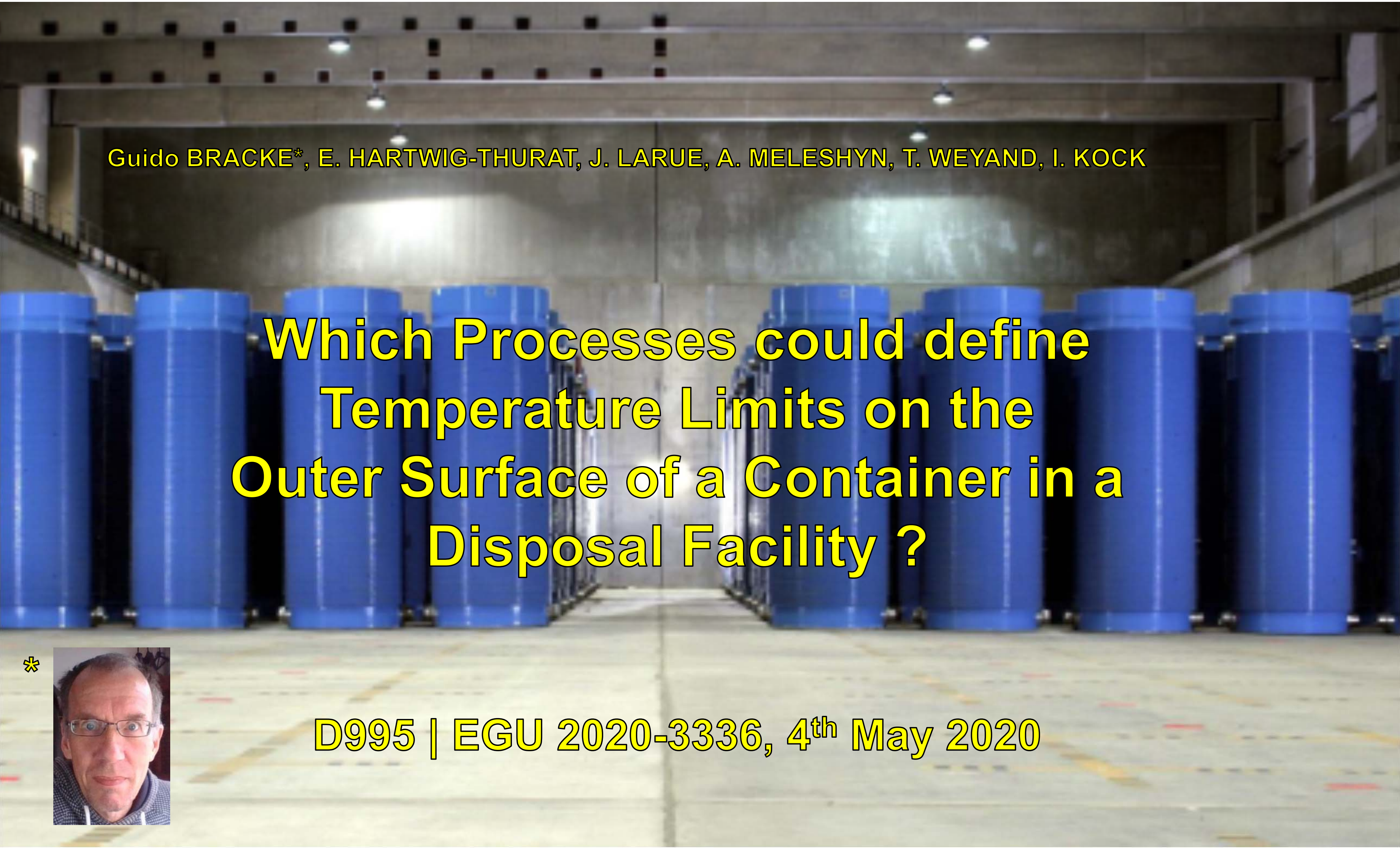

Guido BRACKE*, E. HARTWIG-THURAT, J. LARUE, A. MELESHYN, T. WEYAND, I. KOCK

Which Processes could define Temperature Limits on the Outer Surface of a Container in a Disposal Facility ?

*

D995 | EGU 2020-3336, 4th May 2020

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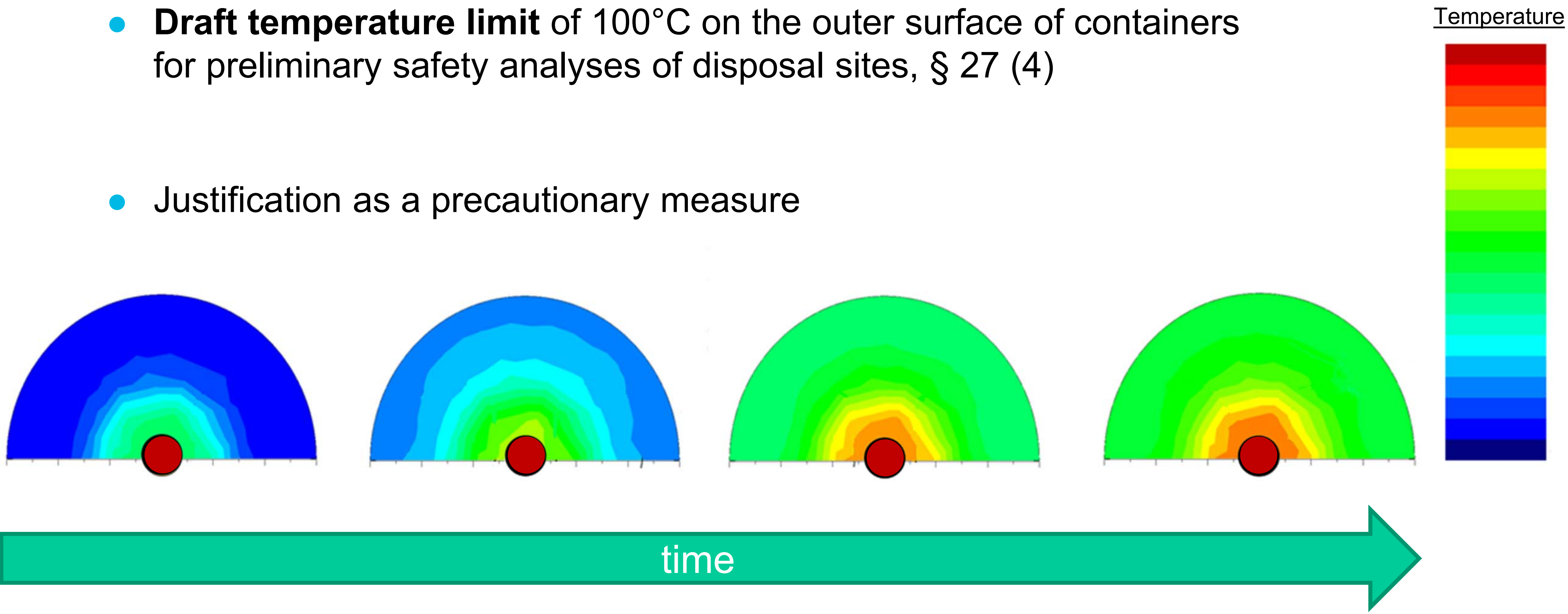
Site selection act (2017) for disposal of HLRW

- **Draft temperature limit** of 100°C on the outer surface of containers for preliminary safety analyses of disposal sites, § 27 (4)
- Justification as a precautionary measure



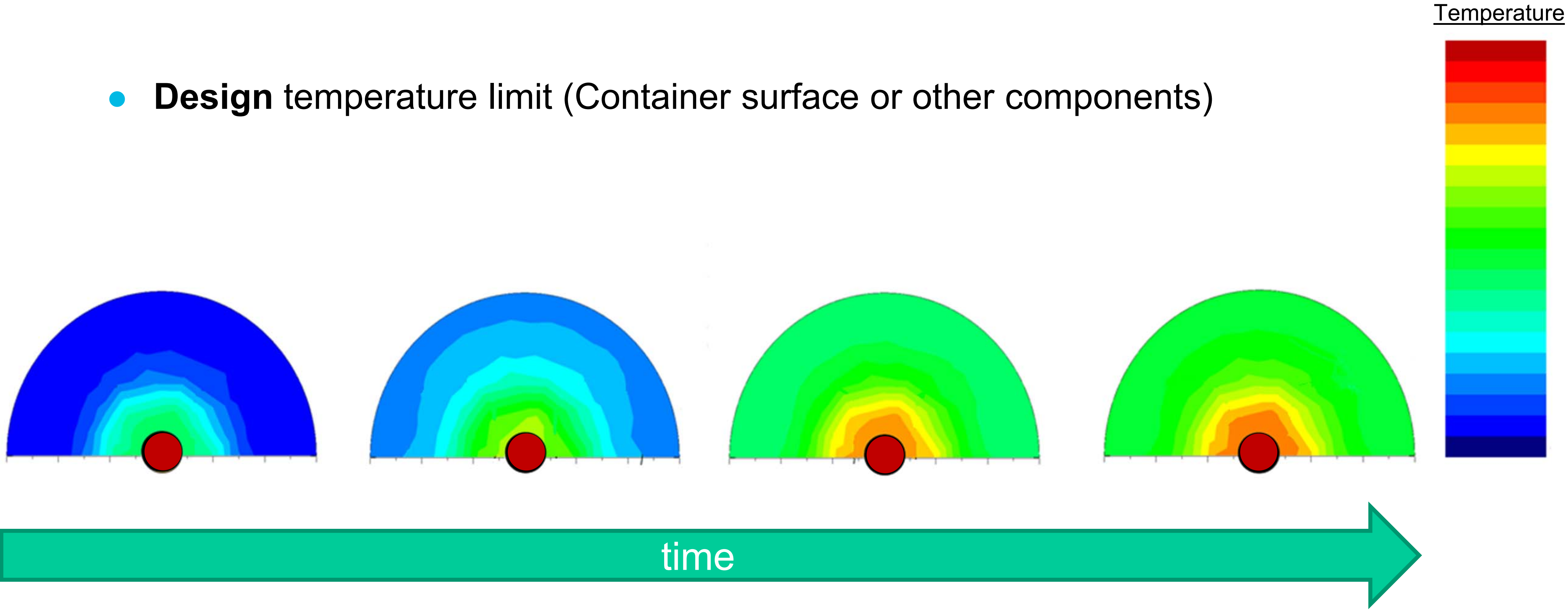
Comments on the „draft temperature limit“*

- Temperatures below 100°C are not necessarily advantageous for safety
- Potential sites may be not be considered
- May impede the development and optimization of safety and disposal concepts

* Reichert (2017), Röhlig (2017), Watzel (2017)

Definitions

- **Draft** temperature limit (as given in §27 (4) for container surface)
- **Design** temperature limit (Container surface or other components)

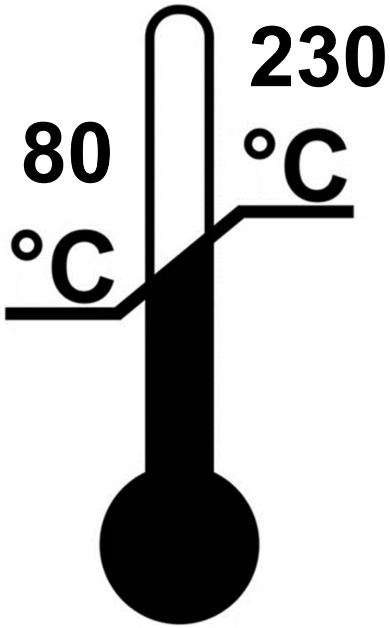


Are there any national regulations on temperature limits elsewhere ?

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

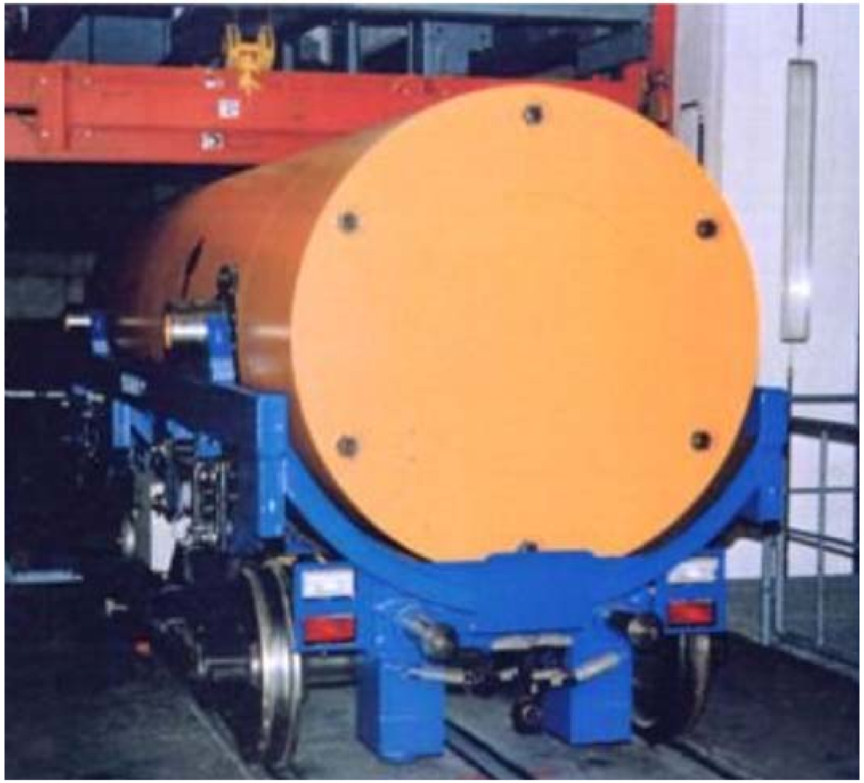
However:

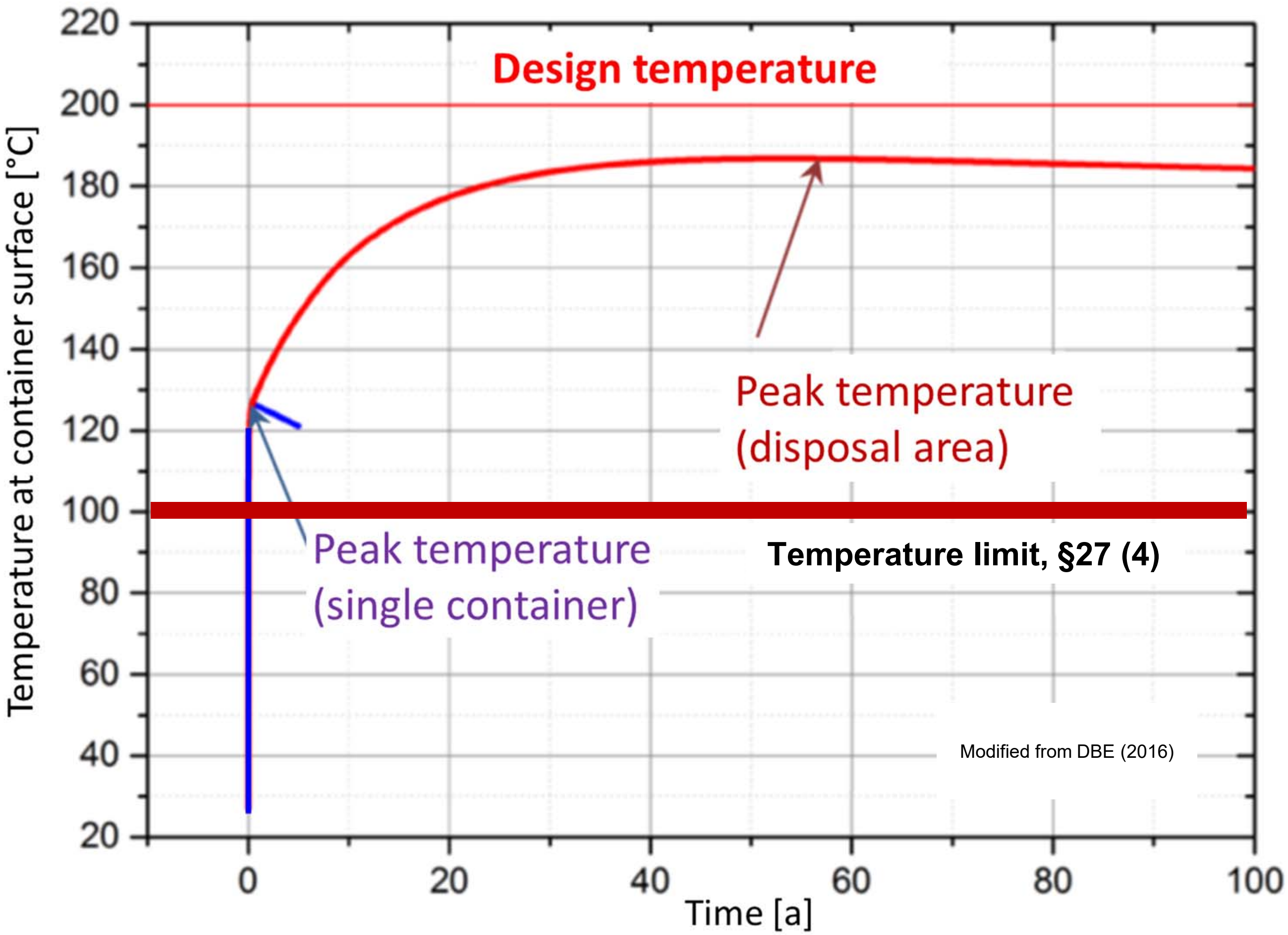
- Some general requirements on design temperatures in guidelines !
- **Applied design temperatures** for the surface of containers range between 80 - 230 °C (existing safety and disposal concepts)



* See also: D1016 | EGU2020-20302, State of the scientific and technical knowledge about limiting temperatures in the Repository Site Selection process of Germany with simultaneous consideration to Europe and other European repository concepts, Ute Maurer-Rurack, Axel Liebscher, and Fabien Magri

Temperatures of a POLLUX container of disposal concept for Gorleben

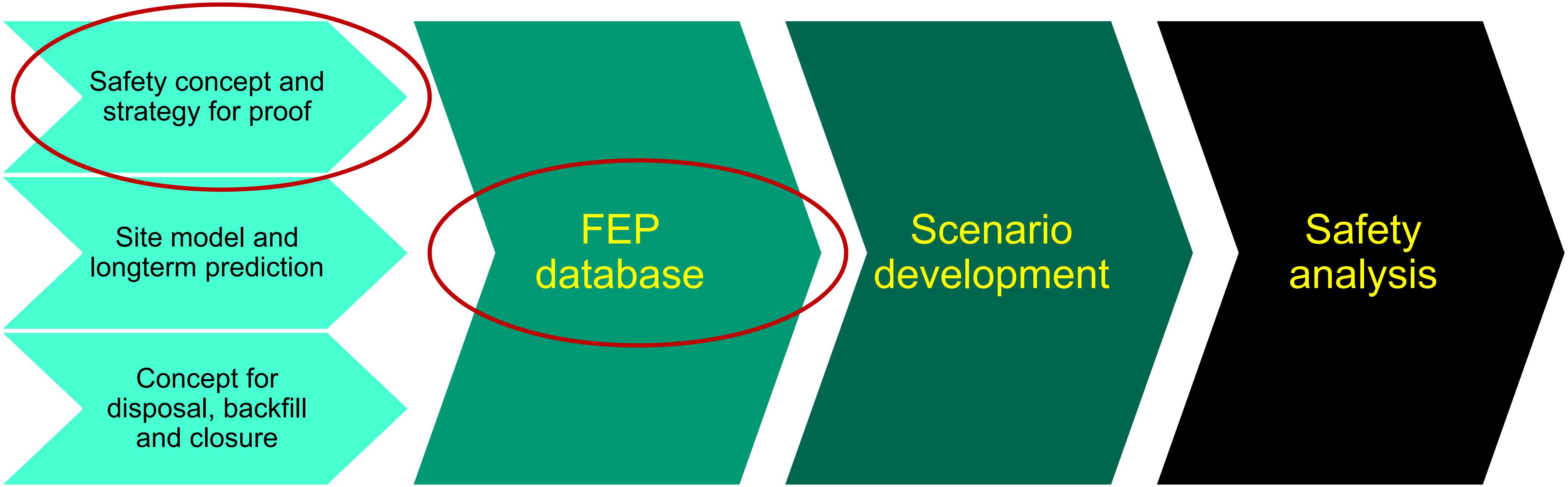




Impact of „design temperature limits“ for generic disposal concepts (DBE 2016)

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

Building blocks for a safety analysis

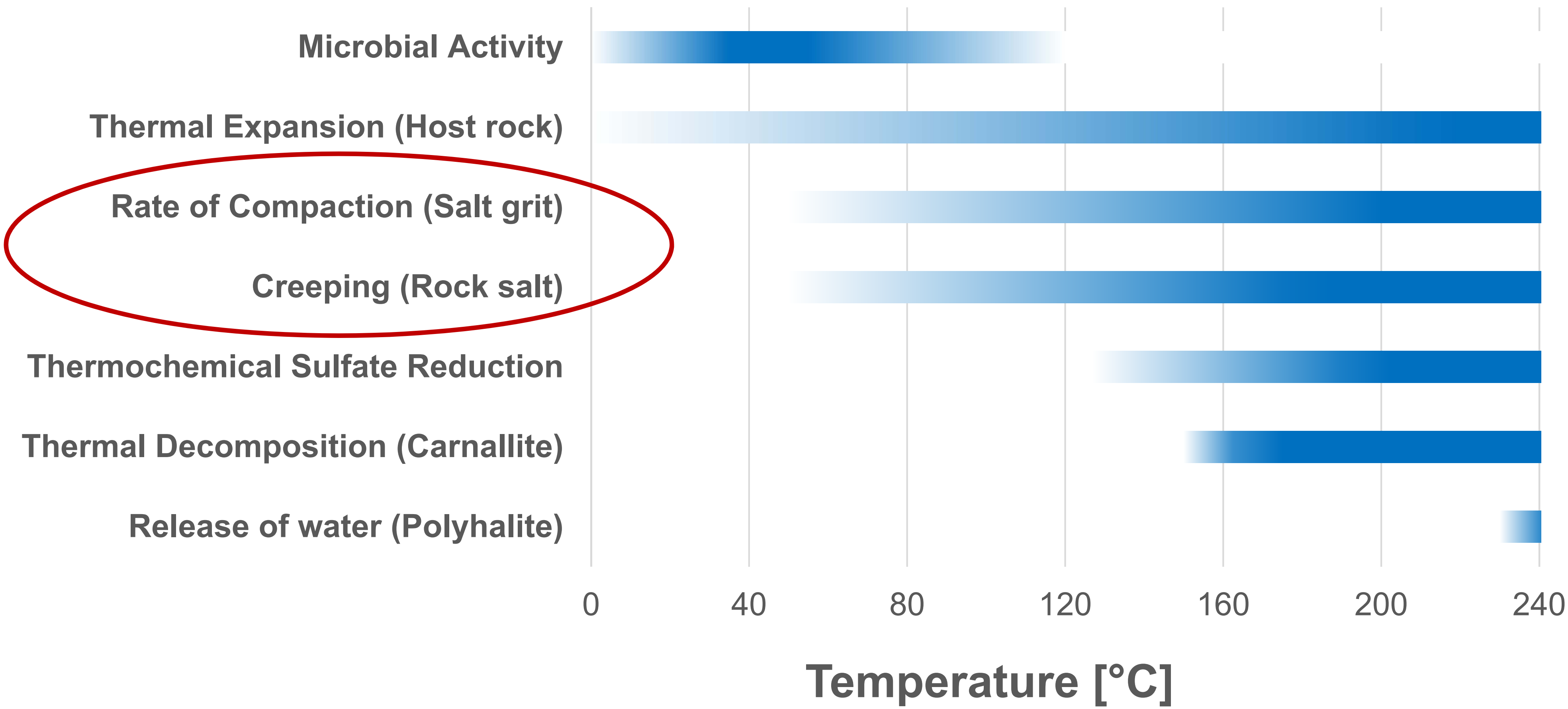


Processes in FEP-Catalogues (Features, Events and Processes)

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

Examples

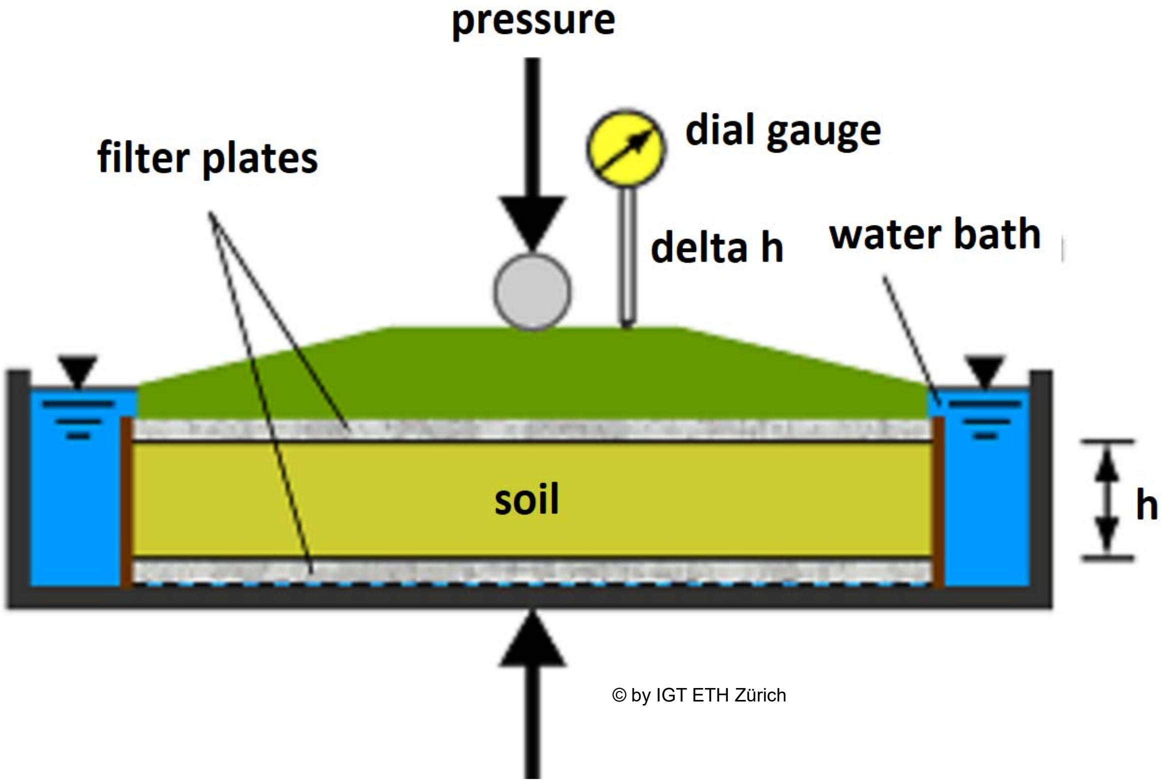
Rock salt: main temperature-dependent processes for safety concepts



Modified from Bracke et al. (2019)

Oedometer tests on crushed salt used for backfill

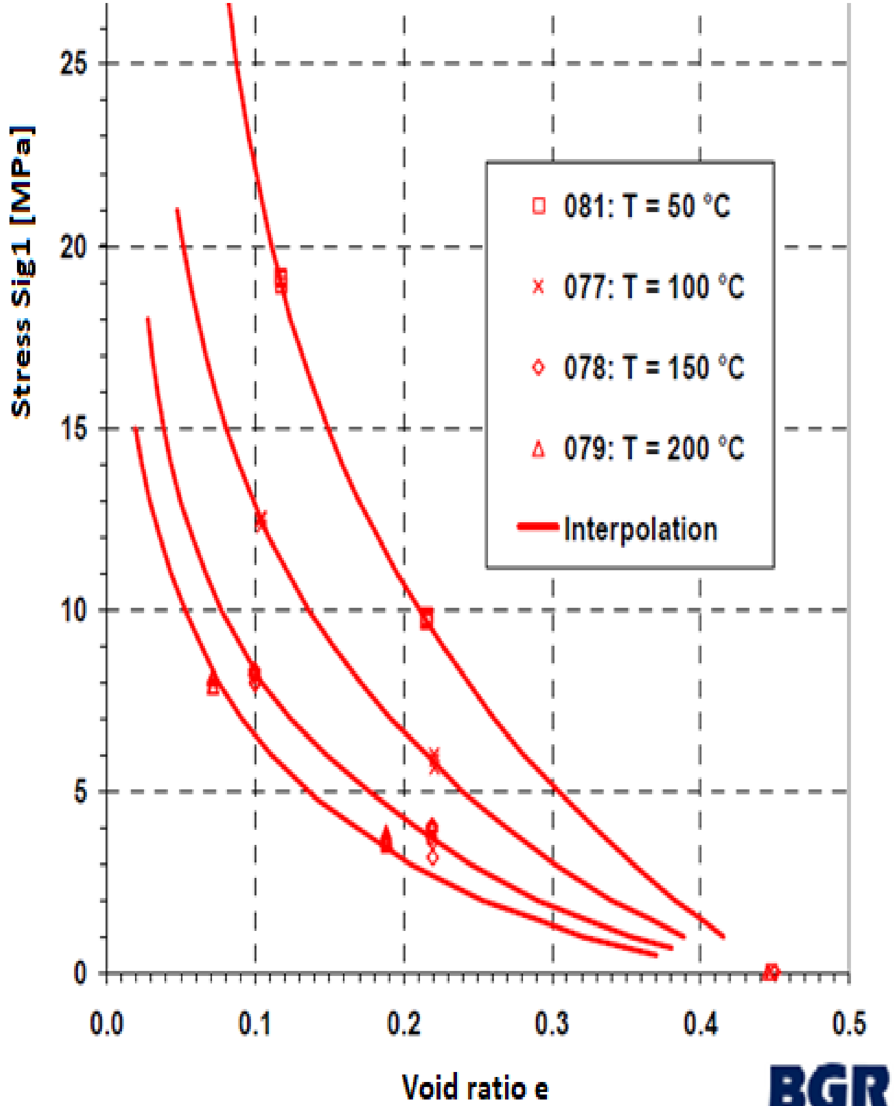
- Stress versus void ratio (porosity)
- Constant **compaction** rate
- Temperatures 50 – 200 °C



Oedometer tests on crushed salt for backfill

⇒ **Higher** temperature:
Lower porosity at **lower** stress

⇒ **Positive effect !**



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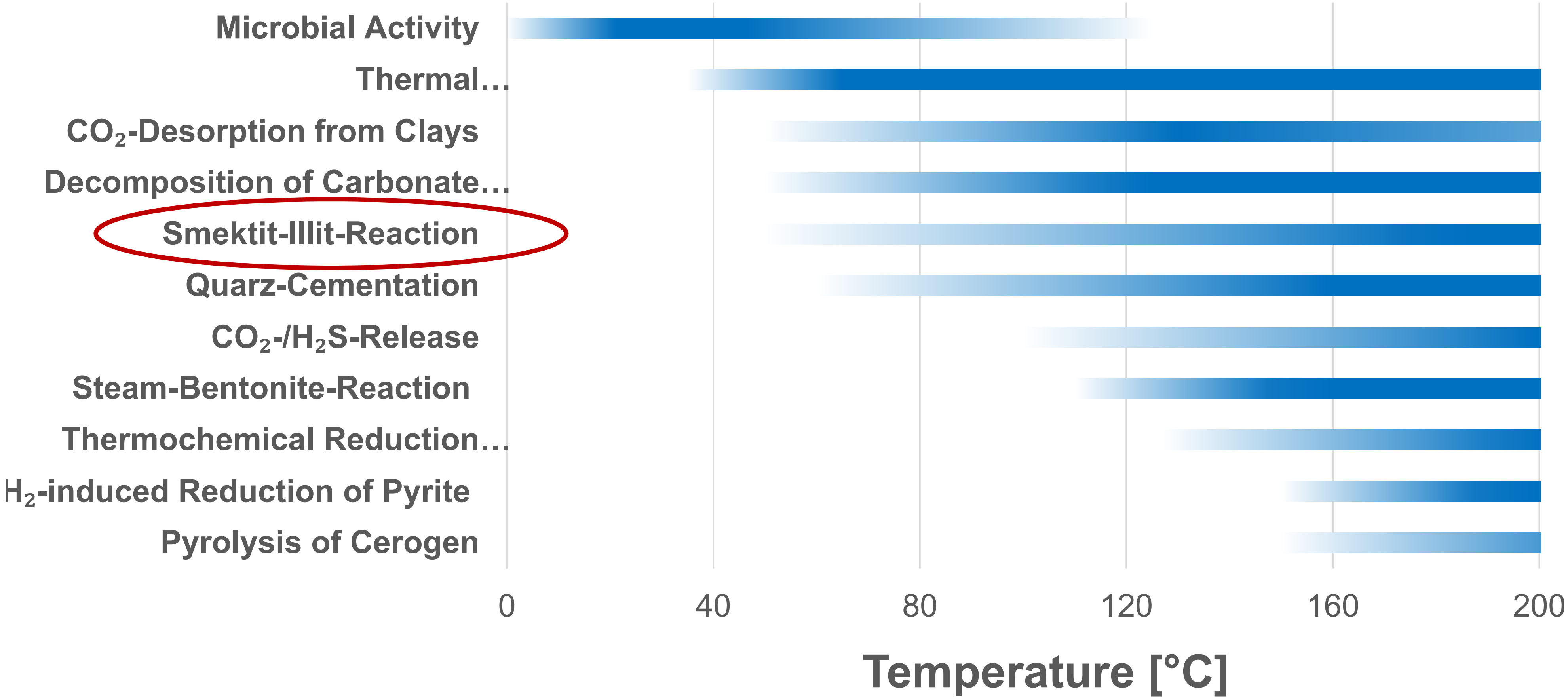
Clay rock – main temperature-dependent processes for safety concepts

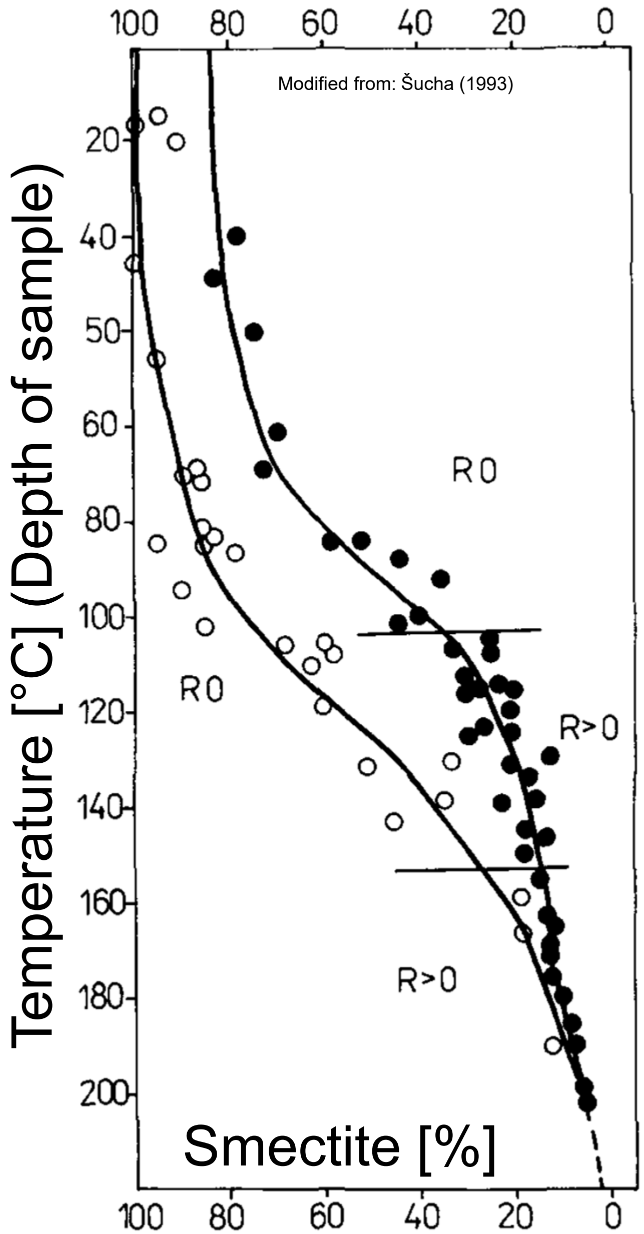


Modified from Bracke et al. (2019)

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

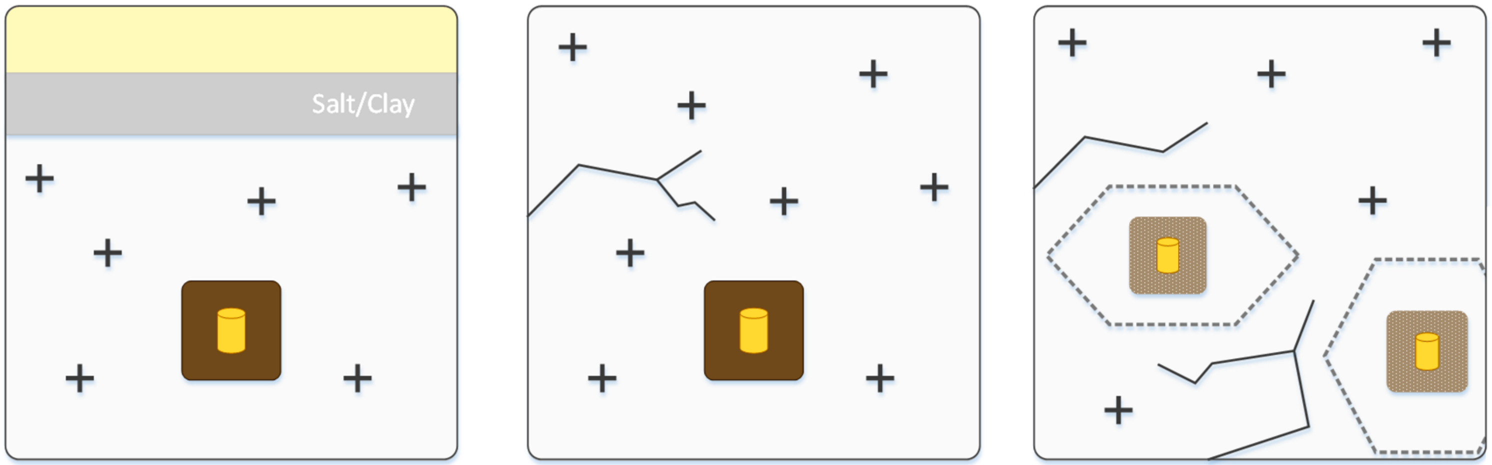
⇒ **Higher temperature: Negative effect !**



Crystalline rock – main temperature-dependent processes for safety concepts

- Matrix: Consideration of thermal conductivity and heat capacity
- Matrix: High temperatures in history ⇒ low mechanical impact by temperature
- However: materials, geotechnical barriers and **fissure fillings** (e.g. hydrothermal alterations) may be relevant for safety concepts

Three concepts: Overlying CPRZ KBS-3 Concept multiple CPRZ



Summary on THMCB processes

- Many temperature-dependent processes and interactions
- Published FEP catalogues list almost all conceivable temperature-dependent processes
- Safety relevance is depending on the safety and disposal concept

Summary and conclusions

- 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** min. or max. **temperature limits** for the outer surface of containers should be based on (preliminary) safety and disposal concepts.

- When a safety concept is set and a disposal concept is optimized and approved, "*temperature limits*" can be **justified** by safety analyses for a disposal facility

Which Processes could define Temperature Limits on the Outer Surface of a Container in a Disposal Facility ?

Main (many) processes are known.

“***Design temperature limits***“ are derived when safety and disposal concepts are selected.

Therefore:

1. Development of feasible safety concepts and preliminary disposal concepts
2. Preliminary safety analyses to find relevant processes and to optimize concepts and design temperatures
3. Derive resilient and (site-)specific “*temperature limits*” based on the interaction of all relevant processes.

References (more in Bracke et al., 2019)

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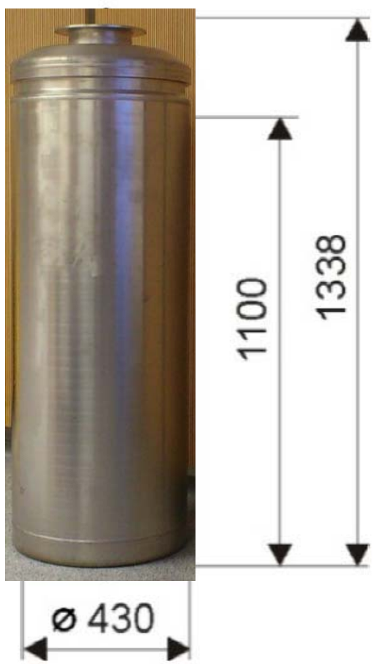
- Watzel, R.: Stellungnahme zur öffentlichen Anhörung des Umweltausschusses am 08.03.2017 zur Fortentwicklung des StandAG. Hrsg.: Deutscher Bundestag (BT), Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Ausschussdrucksache, 18(16)526-G, 2 S.: Berlin, 1. März 2017.

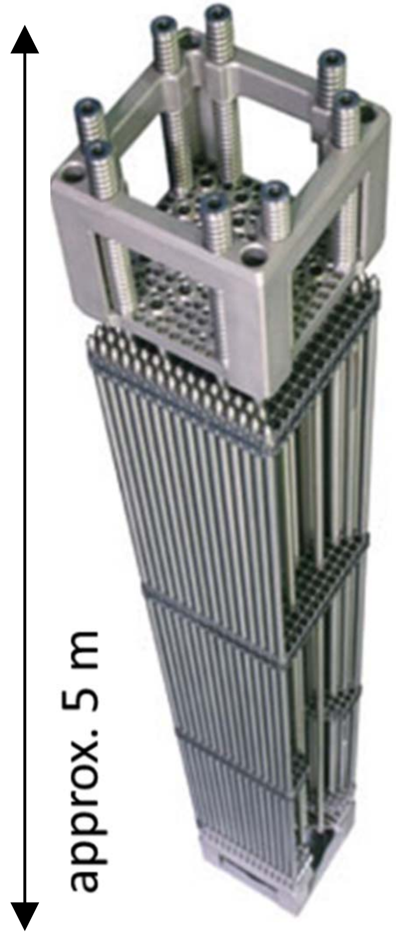
End of presentation !

The following slides are extra stuff.

High-level radioactive waste in Germany (heat generating)

- Spent fuel elements (35000 pieces, 10500 Mg - 7600 m³ as fuel rods)
- Vitrified waste (8000 pieces, 2000 m³)
- Spent fuel pebbles (2000 m³)





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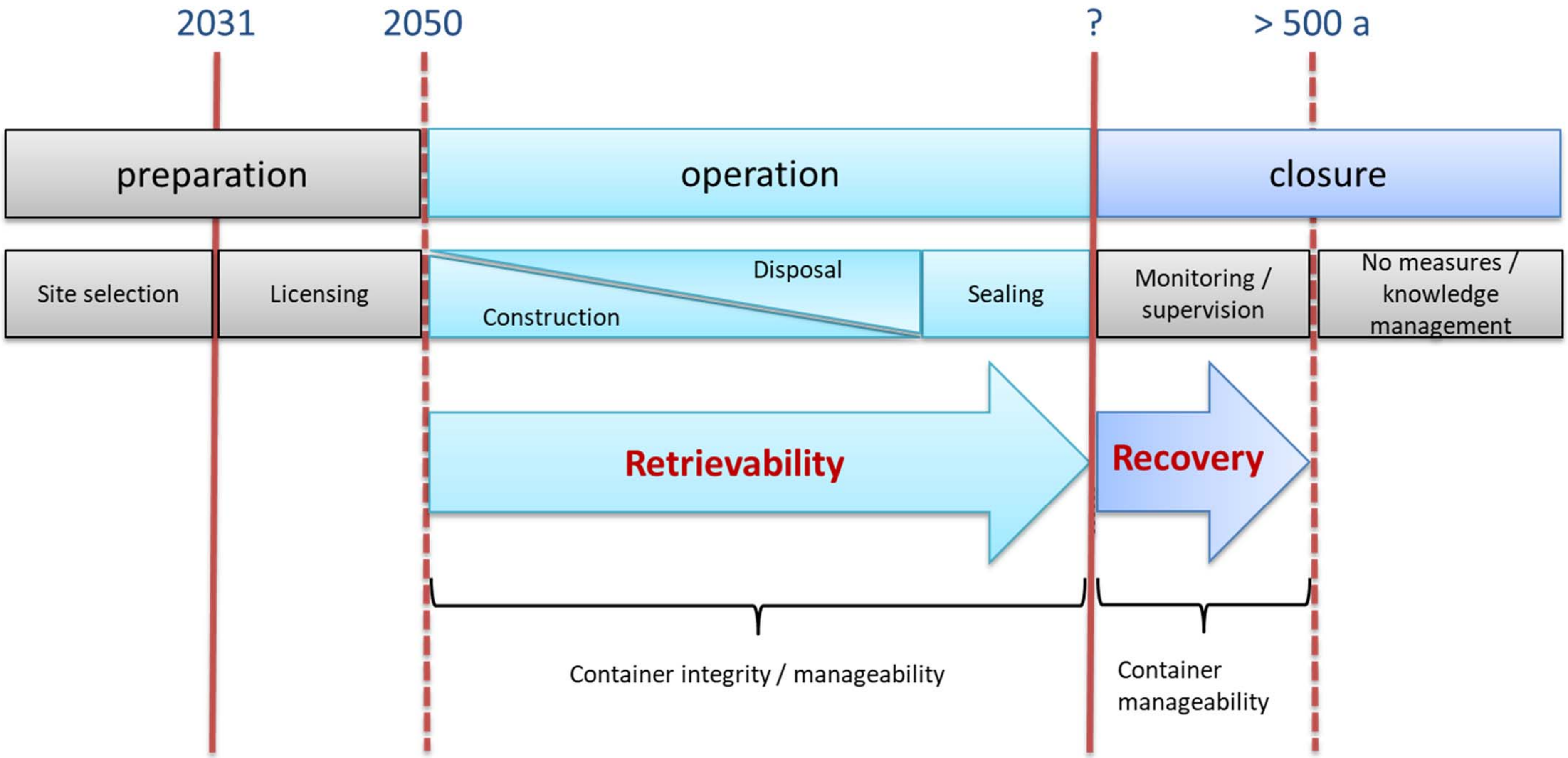
Retrievability / Recovery (operation)



Modified after ESK (2011)

Design temperatures

- Concepts using clay-based materials
  ⇒ mostly ~100 °C as **design** temperature limit (container surface)

- The swiss concept considers a **design** temperature range of **80 – 150 °C** on the container surface

- Concepts in rock salt and tuff applied **design** temperature limits of up to 200 rsp. 230 °C on the container surface

- Mostly based on properties of the rock minerals, water content, … - for a specific safety or disposal concept