DOPAS TRAINING WORKSHOP 2015

Sealing Nuclear Waste Repositories in Salt
The ELSA Experiment

André Rübel (GRS)

D5 4.3.2
18 September 2015

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

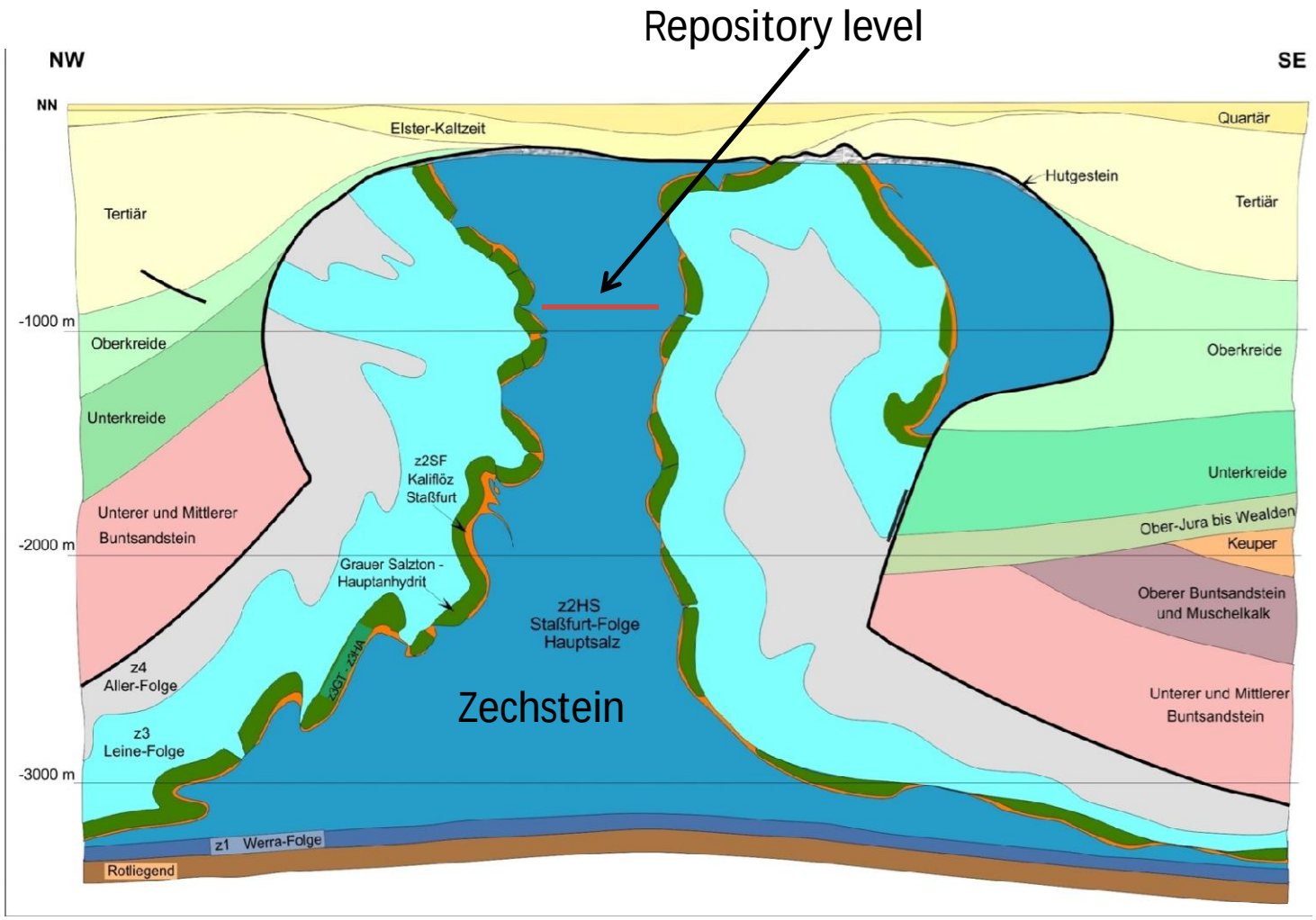
German safety concept for a repository in salt

Background

- Since 1970‘s salt dome Gorleben is investigated as potential site for heat-generating waste
- Start of construction of underground mine in 1986
- Site specific research project on long-term safety 2010 – 2013
  - Preliminary Gorleben Safety Analysis (VSG)
  - ® Sealing concept for salt used in DOPAS is based on VSG work

- 2011: Phase out from nuclear energy in Germany until 2022
- Strategy of the site selection and licensing procedure for a nuclear waste repository for high-level waste in Germany is under discussion
- New start of site selection with “white map”
- Three geologies will be considered in the future
  - Salt, Clay, Crystalline

Geological situation at Gorleben site



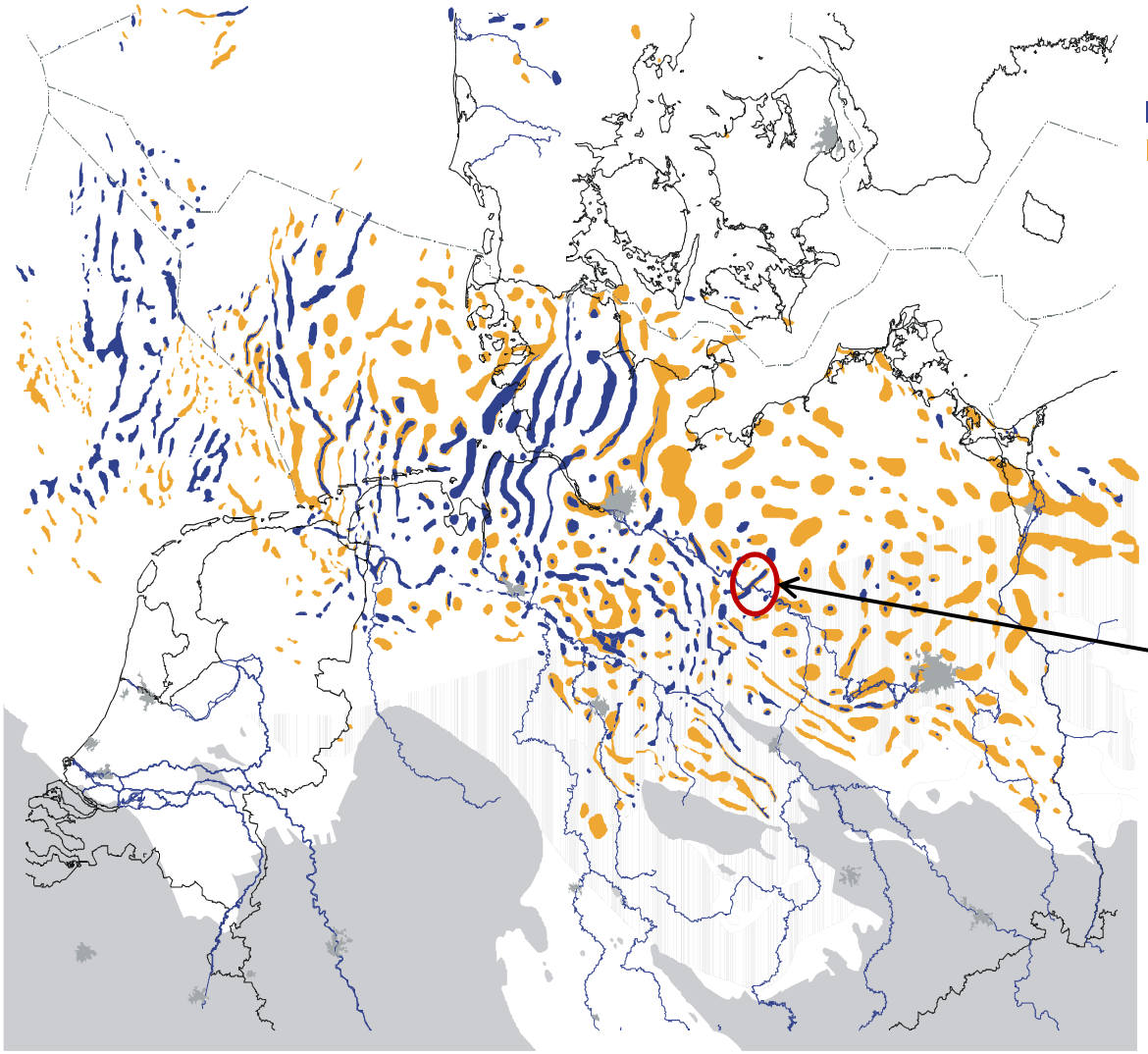
(c) BGR

View into the Gorleben underground mine

(c) BfS

Salt structures in Germany

Perm (296-251 million years)

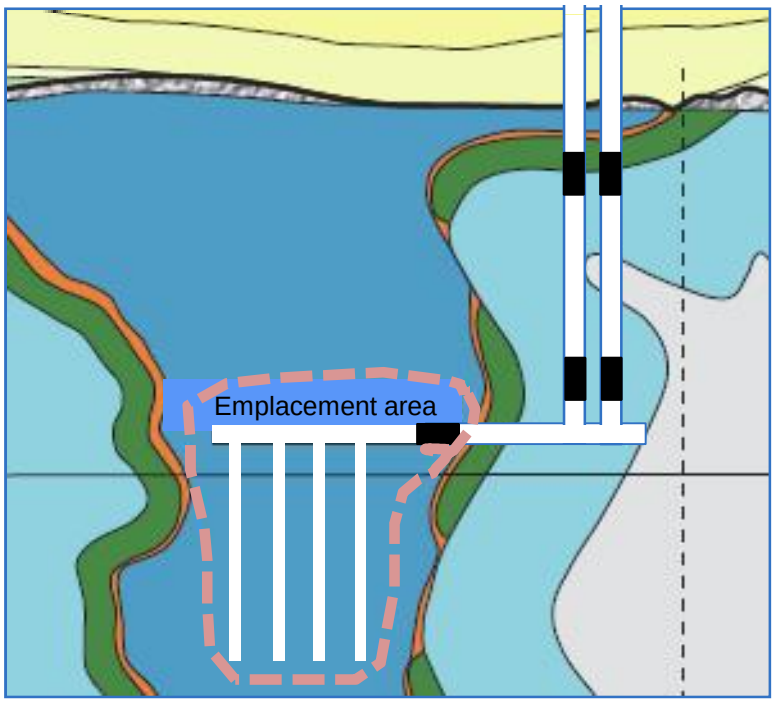


BGR

Safety concept (general)

German Safety Requirements (2010)

- Radioactive waste must be concentrated and contained in the Isolating Rock Zone (ewG)
- No intervention or maintenance work is required during the post-closure phase
- The isolating rock zone is part of the repository system which, in conjunction with the technical seals ensures containment of the waste.
- Release of radioactivity only negligibly increases the risks associated with natural radiation exposure
- Allowance for simplified radiological statement at ewG boundary



Safety concept salt

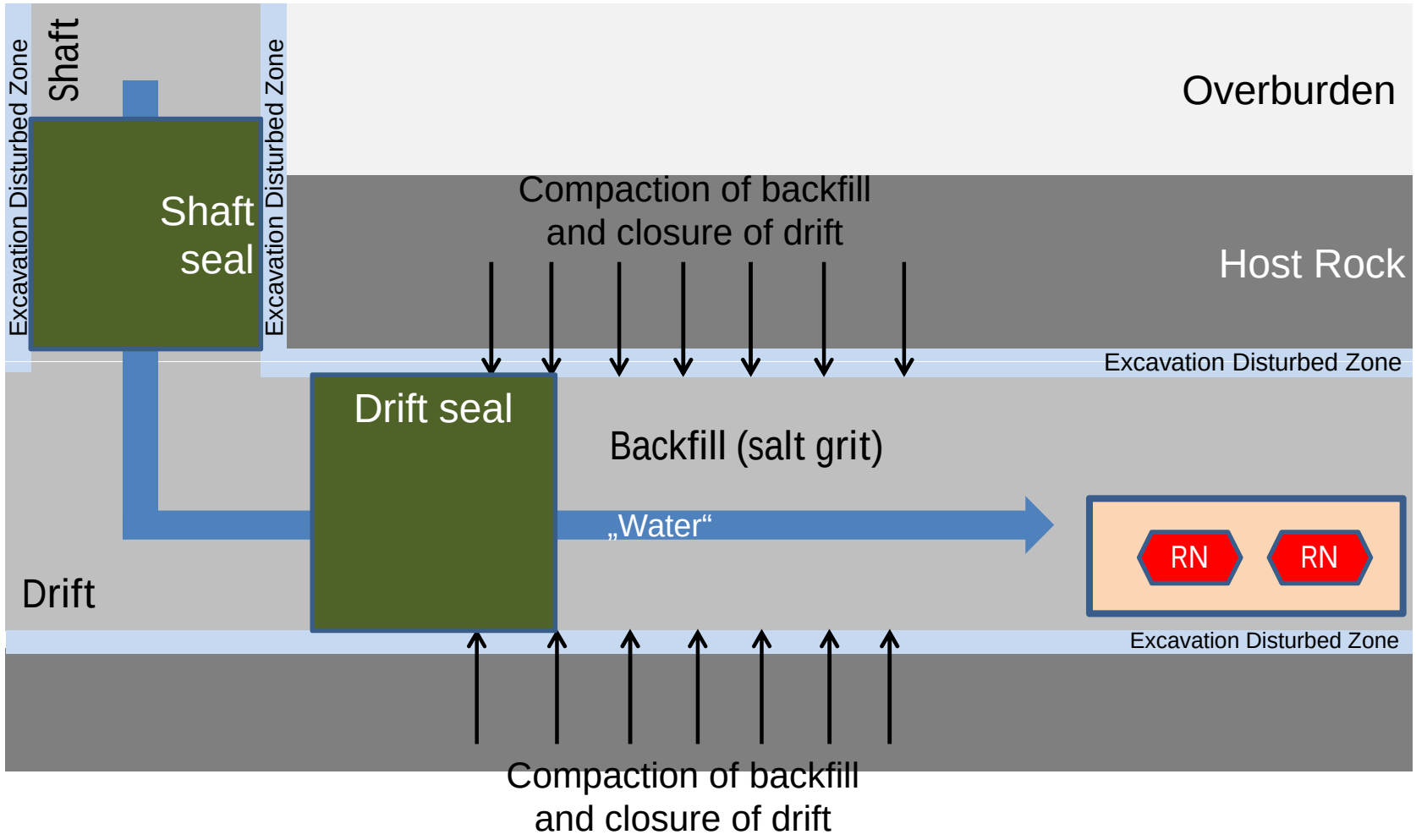
Preliminary Gorleben Safety Analysis (VSG)

- Isolation should be achieved by minimizing contact of the waste with water
- For probable evolutions of repository it is strived for that no or at the most very small amounts of external water gets in contact with the waste
- Salt host rock is dry and impermeable for water, inflow only through drift system

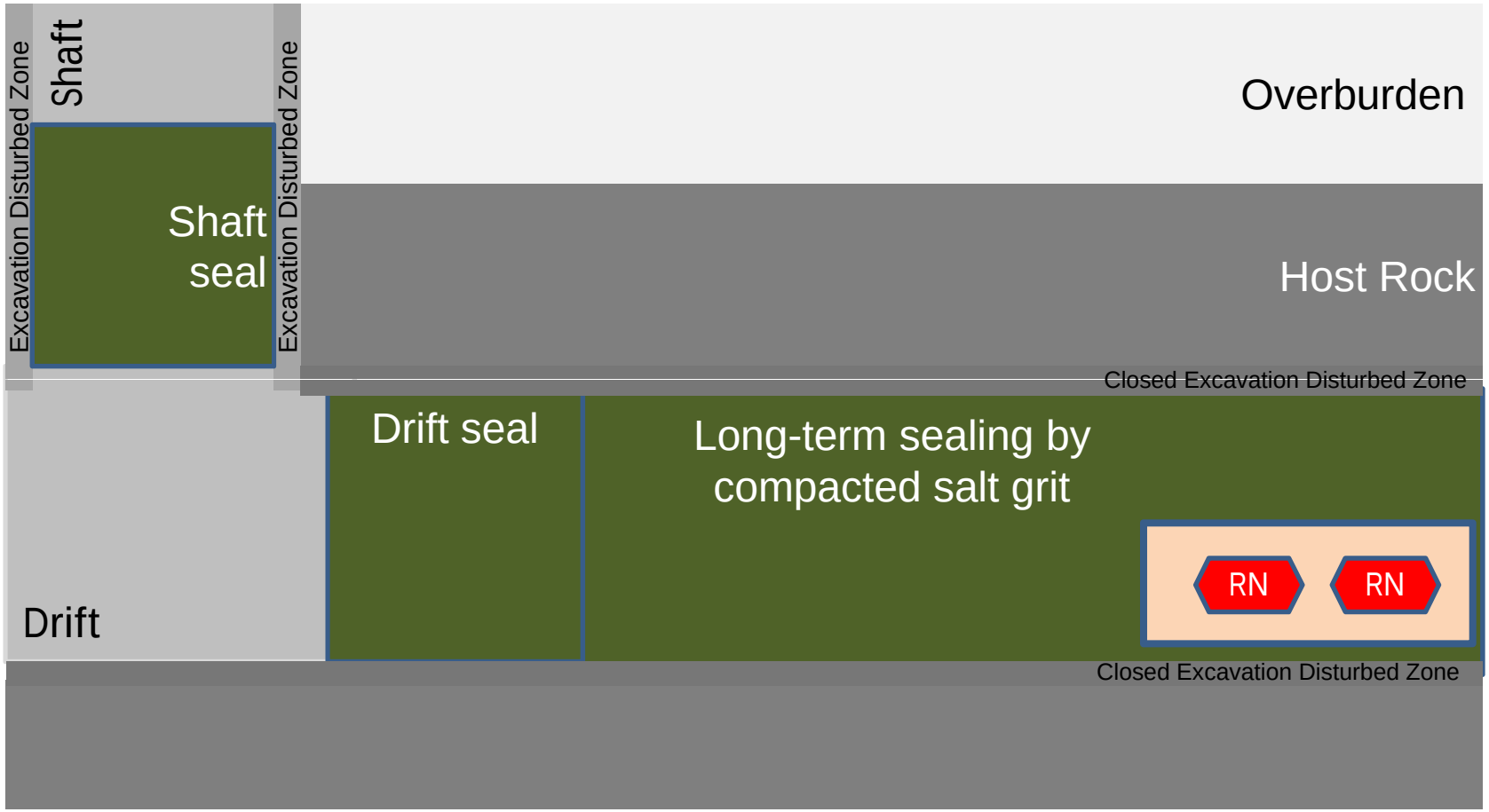
→ Sealing of shaft and access drifts is of high importance for the safety concept

- Short term: Constructed shaft and drift seals
- Long term: Compacted salt grit backfill in access drifts
  - Salt grit is compacted by convergence of the salt host rock
  - Pre-compaction is used to speed up compaction process
  - Addition of 0.6% of water is discussed to speed up compaction process
  - Compaction under these circumstances within a few 1 000 of years to a permeability to less than 1E-19 m^2

Safety concept salt

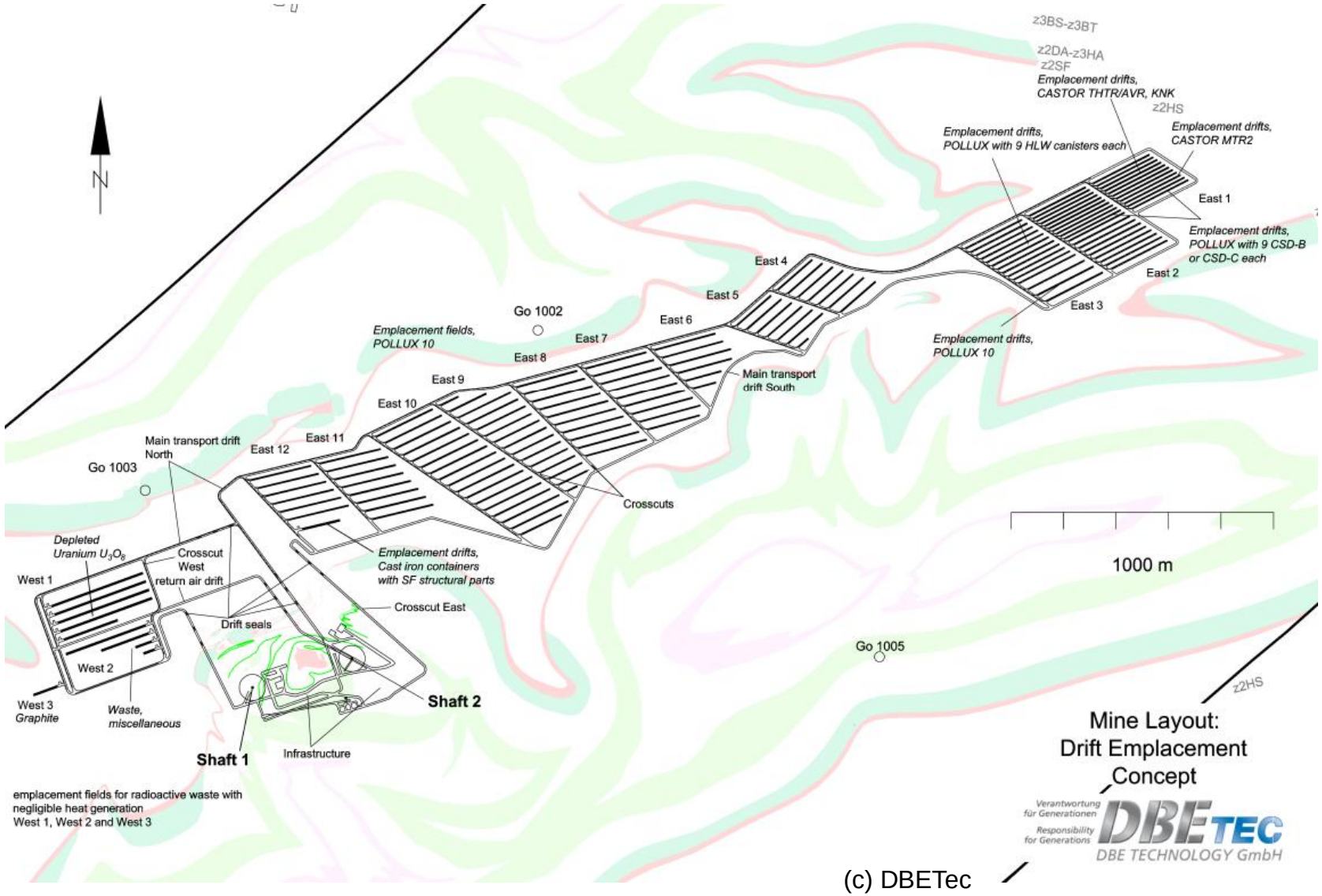


Safety concept salt



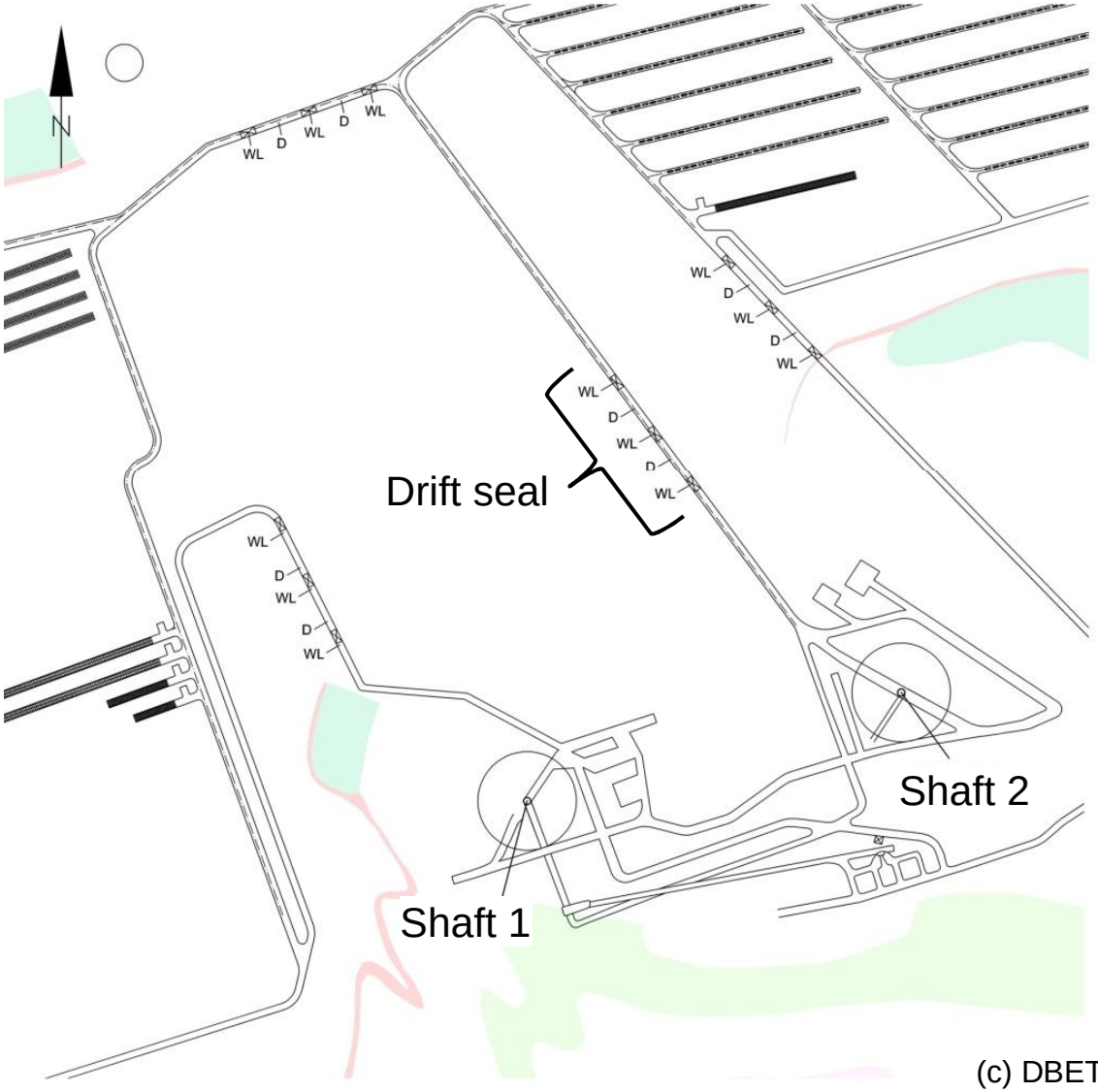
Repository concept for a high-level waste repository at Gorleben

Repository layout (drift emplacement concept)



(c) DBETec

Infrastructure area and drift sealing system



D = sealing element
WL = static abutment

(c) DBETec

Boundary conditions

Envisaged life time of shaft sealing is 50 000 years

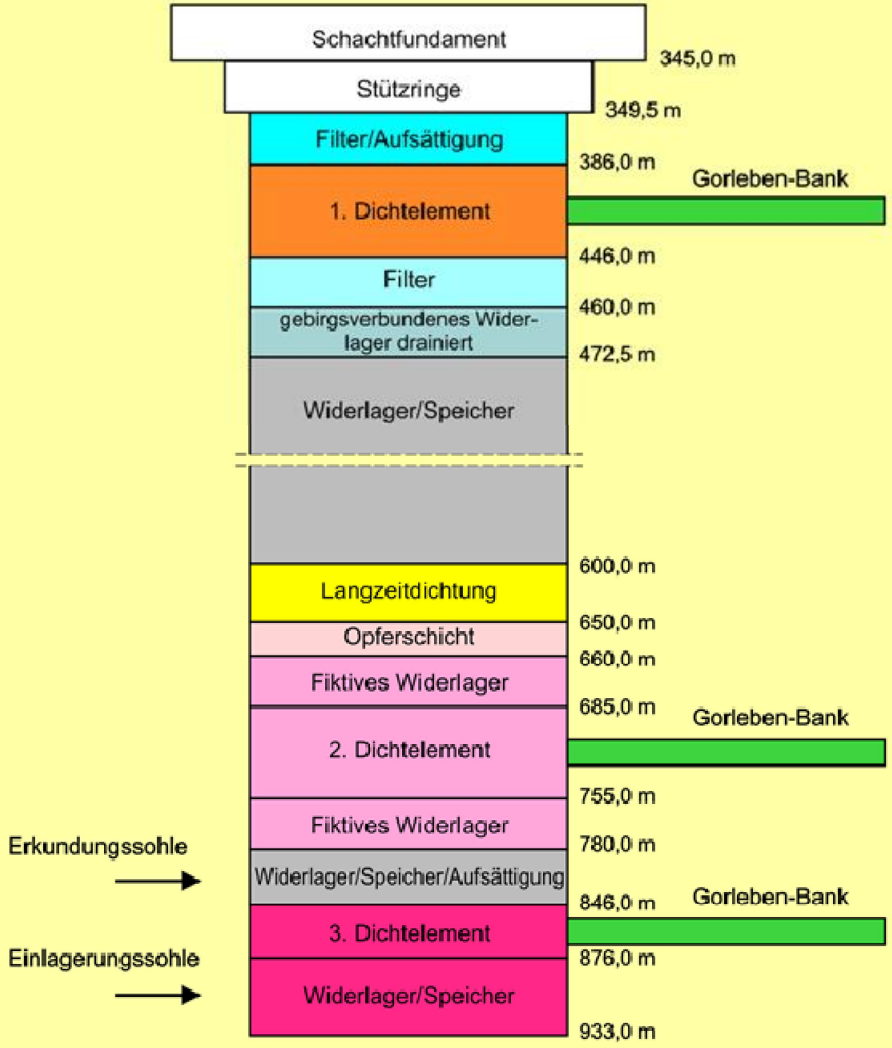
Materials

- Bentonite
- Crushed salt (long-term sealing)
- Salt concrete (cement and crushed salt)
- Sorel concrete (MgO as adhesive cement and crushed salt as aggregate)

Main Impacts

- Mechanical
  - Forces and tensions like weight, rock pressure, fluid pressure...
  - Distortions like swelling/shrinkage, creep/relaxation...
- Chemical
  - Dissolution and alteration from solutions and gases
- Temperature induced effects

Shaft sealing system



(c) DBETec

Shaft foundation
Support rings
Drainage layer (sand/gravel)
1. Sealing element (bentonite)

Drainage layer (basalt gravel)
Abutment (salt concrete)

Abutment/reservoir (basalt gravel)

Long term sealing (compacted salt grit)
Sacrificial layer (salt concrete)
Abutment (salt concrete)

2. Sealing element (salt concrete)

Abutment (salt concrete)
Abutment/reservoir (basalt gravel + bischofite)
3. Sealing element (sorel concrete)

Abutment (sorel concrete)

Work on sealing material in DOPAS and related projects

ELSA - Experiment

Phase 1 (completed)

§ Boundary conditions and requirements for shaft seal

Phase 2 (running)

§ Experimental investigations and process modelling

- Optimization of the preliminary shaft sealing concept
- Material selection and characterization (Lab tests)
- Further development and (in-situ) test of
  - compaction procedures of salt grit or salt grit/bentonite mixtures
  - injection procedure (EDZ)
  - specific bitumen elements
  - accelerated and uniform bentonite plug saturation

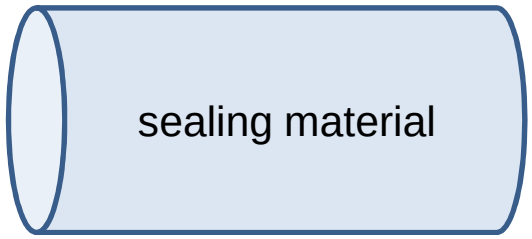
Phase 3 (future)

§ Large scale in-situ demonstration test of individual functional shaft sealing components

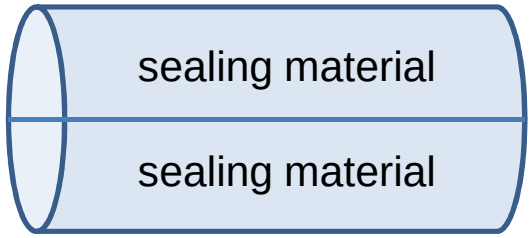
Geochemical laboratory experiments and modelling (GRS)

Static and flow corrosion experiments on salt concrete and sorel concrete with different porosities and different solutions

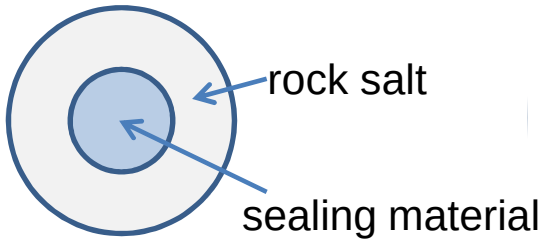
Matrix corrosion



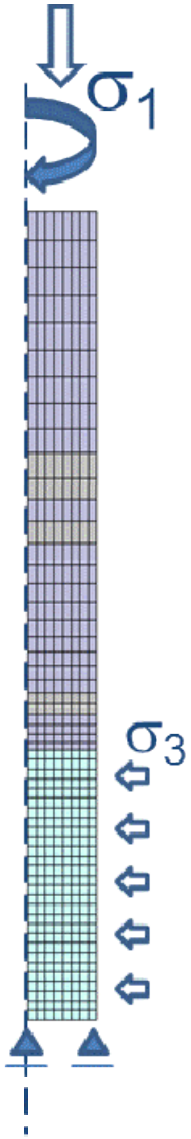
Corrosion on cracks



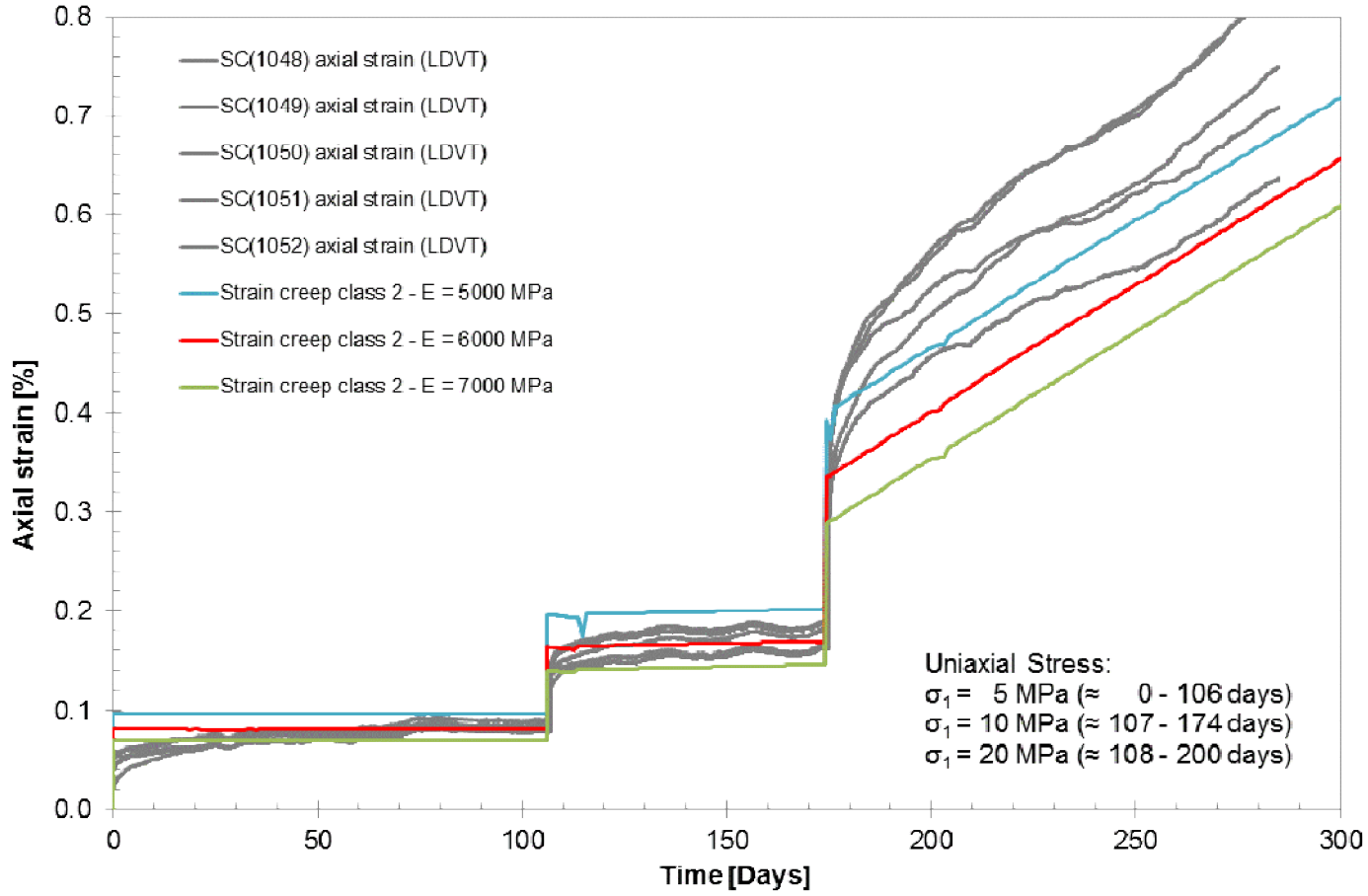
Corrosion at interfaces



Geotechnical laboratory experiments and modelling (GRS)

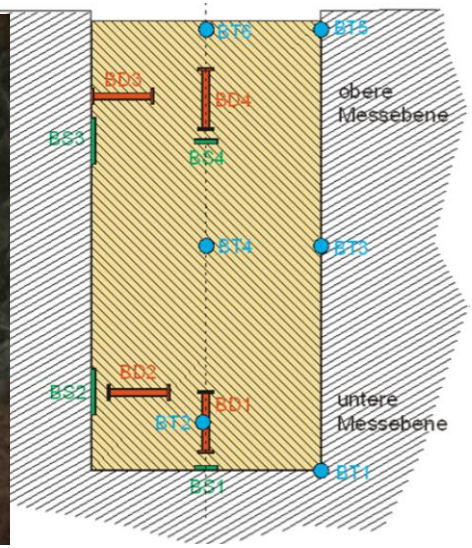


Uniaxial creep



Mid-Scale in situ testing on material behaviour (DBETec)

- In-situ test using sorel concrete
  - Large borehole including monitoring equipment has been filled
  - Wait for stable conditions (hardening)
  - Permeability measurements



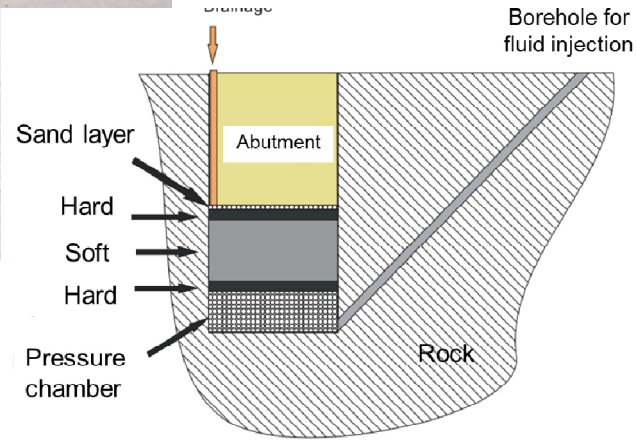
DBETec

Mid-Scale in situ testing on material behaviour (DBETec)

§ In-situ test using bitumen and asphalt

- Permeability ≤ 3E-21 to 6E-20 m² for bitumen and ≤ 3E-20 m² for asphalt

DBETec



In-situ testing on emplacement and compaction procedures (DBETec)

Total porosity: 13.3%
Permeability (brine): 6.6E-16 m^2 (start)
1,8E-19 m^2 (end, 22h)

DBETec

Future steps in ELSA experiment

Large scale in-situ demonstration test of individual functional shaft sealing components

- Already done prior to DOPAS:
  - Large scale in-situ experiment on gravel column as shaft filling material
  - Large scale in-situ experiment on bentonite shaft sealing element
  - Large scale in-situ experiment on salt concrete drift sealing

- Locations for future experiments to be found for experiments on shaft sealing elements from
  - Salt concrete
  - Sorel concrete
  - Crushed salt (Long-term sealing element)

§ Copyright notice

- This material can only be used for non-commercial use
- If no reference given, pictures in the presentation by GRS

§ References for further reading:

- Reports of the Preliminary Gorleben Safety Analysis (VSG) (mainly in German): http://www.grs.de/endlagersicherheit/gorleben/ergebnisse
- Jobmann, M. (2013). Requirements for shaft seals for HLW repositories in Germany, Technical Report, translated extraction from (Kudla et al. 2013), DBE TECHNOLOGY, Peine. http://www.posiva.fi/files/3562/Requirements_shaft-sealing_Germany.pdf
- Herold, P. & Müller-Hoeppe, N. (2013). Safety demonstration and verification concept - Principle and application examples - Technical Report, translated extraction from (Kudla et al. 2013), DBE TECHNOLOGY GmbH, Peine. http://www.posiva.fi/files/3563/Safety_demonstration_for_shaft_sealing_elements_Germany.pdf

Acknowledgement

The research leading to these results has received funding

from the European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013,
under Grant Agreement No. 323273 for the DOPAS project

and contracts
02E11122, 02E11132, 02E10377, 02E11142, 02E11193 A and B
from the German Federal Ministry of Economic Affairs and Energy (BMWi).