Assessment methods to compare the expected long-term performance of sealing elements

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Motivation

Shafts and ramps can be used as connections between the surface and underground facilities of a geological disposal facility. The decision depends on various factors. The list of related assessment criteria is long, however, those concerning construction and operation predominate. Long-term relevant criteria are underrepresented in the progress of decision making. The goal of this work is to provide a general method of how to compare the long-term performance of sealing systems in shafts and ramps and thus develop an additional assessment criterion for the selection of suitable surface connections.

Method

For the assessment of the sealing performance, three basic indicators were defined:

Indicator of resistance

➤ takes into account the hydraulic resistance of the barrier system. As simplification a sealing system is assumed as a series of (hydraulic) resistances. Every sealing element consists of partial resistances in parallel sequences (sealing body, contact zone, and EDZ). The resistance against advective flow can be described by:

$$R_i = \frac{L_i * \mu}{A_i * k_i} \quad ; \quad v = \frac{\frac{1}{R} * \Delta p}{A} ; \quad R_{total} = \sum_i R_i$$

Indicator: $I = \dfrac{\frac{v}{v_{limit}}(shaft)}{\frac{v}{v_{limit}}(ramp)}$

Criterion: $\frac{v}{v_{limit}} \leq 1$

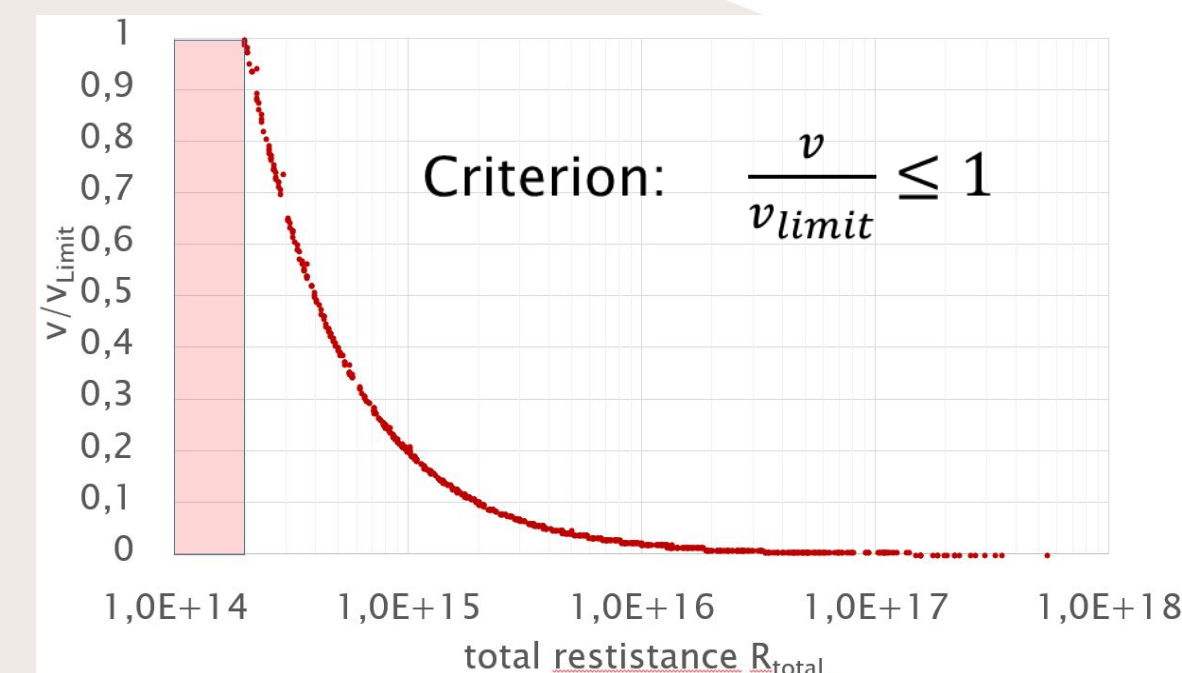Fig. 1 Velocity criterion as a function of resistance

I < 1 advantage shaft
I > 1 advantage ramp

A system not satisfying the criterion $\frac{v}{v_{limit}} \leq 1$ should be avoided in order to provide a hydraulic resistance that allows a safe enclosure within 1 million years.

Indicator of retention

➤ takes into account the retention properties of the sealing materials (e.g. bentonite or concrete-based materials)

Indicator: $I = \dfrac{retaining\ mass\ (ramp)}{retaining\ mass\ (shaft)}$

Indicator of robustness

➤ means the insensitivity of the barriers to internal and external influences and disturbances
a) Robustness by design principles redundancy and diversity:
1   one element
2   same element twice
3   same material in different design versions
4   different materials in different design versions
b) Sensitivity of the construction against variations (in progress)
b) Robustness against failures of single components (in progress)

(Preliminary) Results

For the disposal of high-level nuclear waste in Germany, salt, claystone, and crystalline formations are under consideration. For all host rocks, conceptual designs of potential repositories including sealing concepts have been developed.
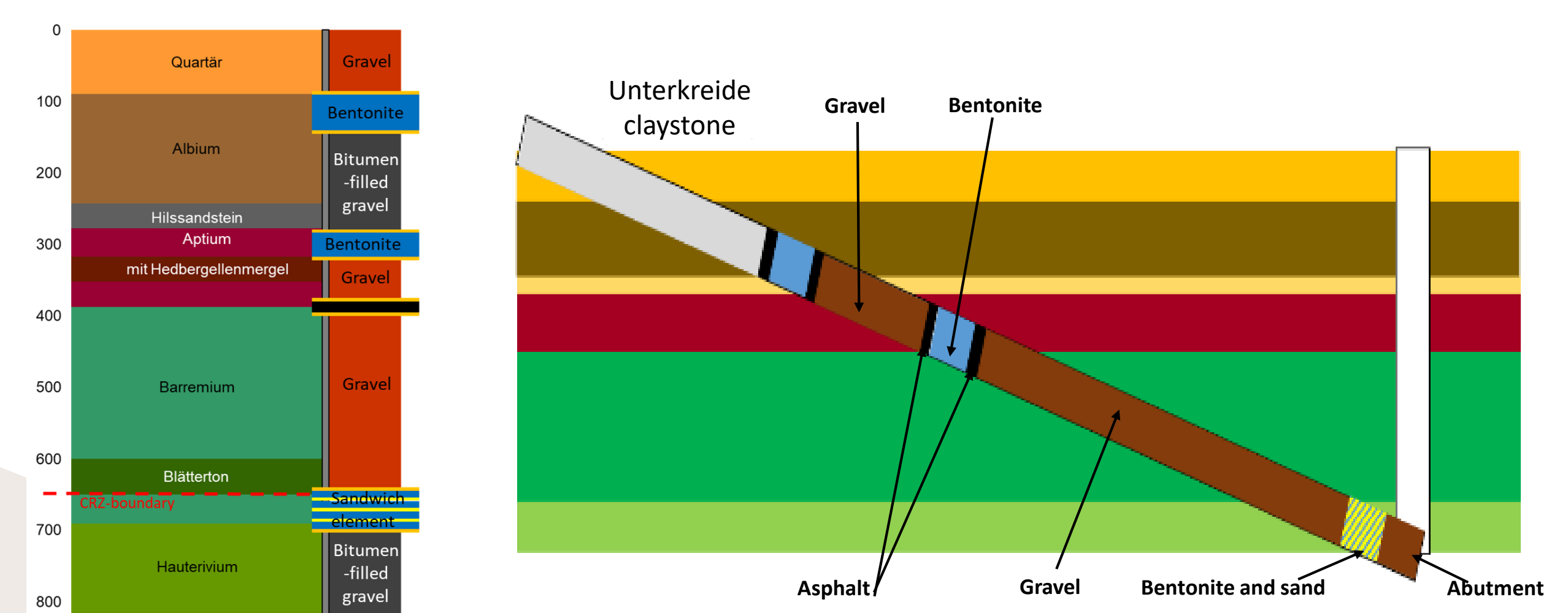Examples of shaft and ramp sealing systems in claystone are illustrated in Fig. 2:

Fig. 2 Shaft seal in claystone (left), ramp seal in claystone (right)

Most sensitive material properties of sealing elements for both shaft and ramp sealing systems with regard to their total maximum hydraulic resistance (R_{total}) are identified by sensitivity analyses using the optiSLang software. Lengths and permeabilities of sealing elements were varied and coefficient of prognosis was determined. Results for shaft and ramp sealing systems in claystone are shown in Fig. 3.
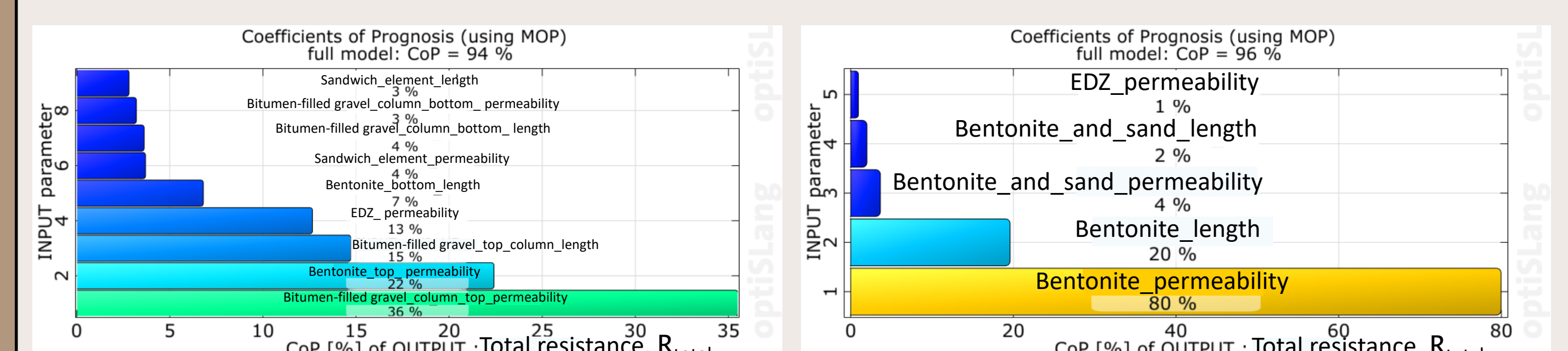

Fig. 3 Coefficients of prognosis (COP) identified for shaft (left) and for ramp seals (right) in claystone (see Fig. 2), preliminary results

The permeability of the sealing elements has a great influence on the hydraulic resistance. Compared with this, length has a reduced impact.

Conclusion and outlook

To compare shaft and ramp seals, different indicators have been defined including resistance, retention, and robustness of the sealing systems. Sensitivity analyses were used to identify the most important material parameters of sealing elements in shaft and ramp systems in claystone in view of the necessary hydraulic resistance. The indicator of hydraulic resistance can be used to define the value range of material parameters that should be avoided in the sealing system in order to provide a hydraulic resistance that allows a safe enclosure within 1 million years. The next steps are the final definition of robustness indicators, the application of all indicators to sealing systems in the different host rocks, and to finally get a more solid basis for a decision regarding the connection between the earth´s surface and the repository.

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