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Supplement of

Discussion of parameters used to distinguish suitable from less suitable HLRW bentonites

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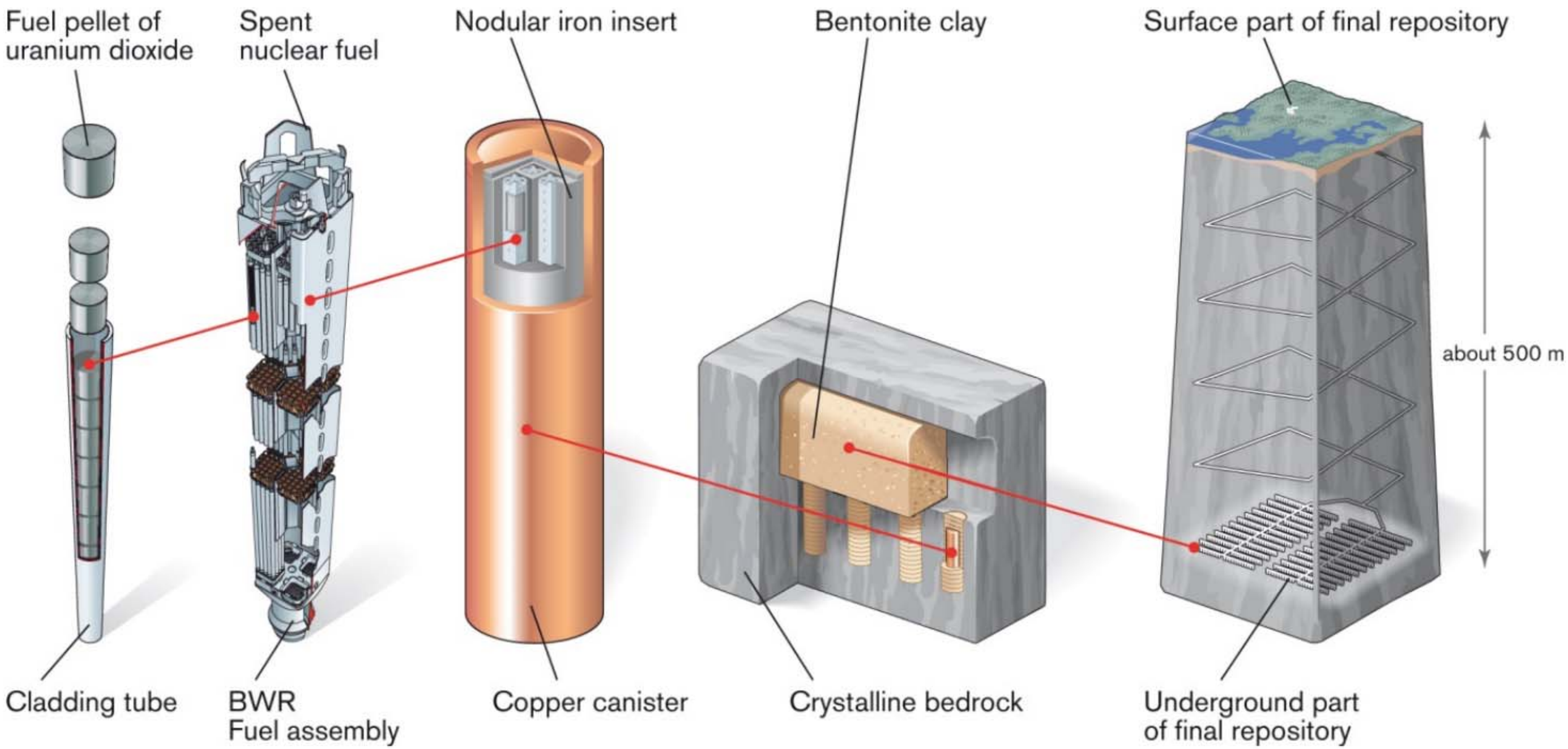
Discussion of parameters which can be used to distinguish suitable from less suitable HLRW bentonites

Bentonite will be used as geotechnical barrier mostly in crystalline rocks

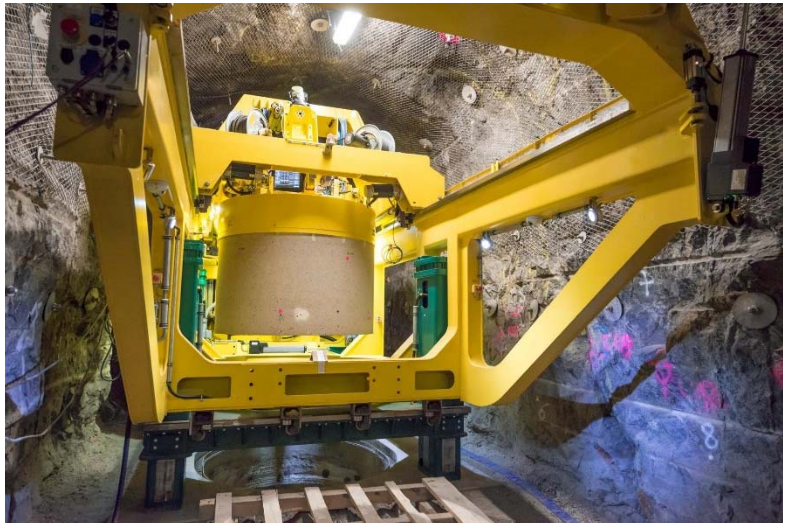
Bentonite:
backfill + blocks



KBS-3 concept (SKB)

Discussion of parameters which can be used to distinguish suitable from less suitable HLRW bentonites

Most relevant: geotechnical barrier
(compacted bentonite blocks to seal canister from crystalline rock)

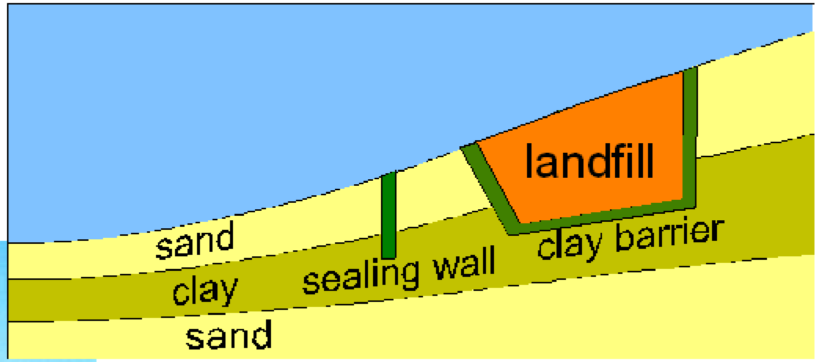


Discussion of parameters which can be used to distinguish suitable from less suitable HLRW bentonites

Why bentonite ?

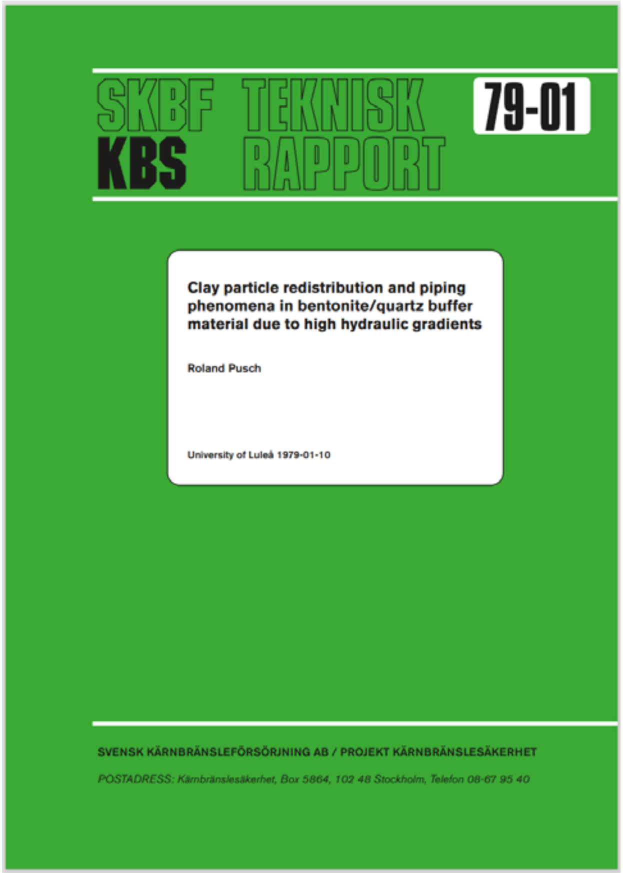
Bentonite = swelling clay = low hydraulic conductivity

since decades: sealing of landfills, contaminated sites, groundwater,…



Discussion of parameters which can be used to distinguish suitable from less suitable HLRW bentonites

SKB started to systematically investigate bentonite as possible HLRW-barrier more than 40 years ago !


SKBF KBS TEKNISK RAPPORT 79-01

Clay particle redistribution and piping phenomena in bentonite/quartz buffer material due to high hydraulic gradients

Roland Pusch

University of Luleå 1979-01-10

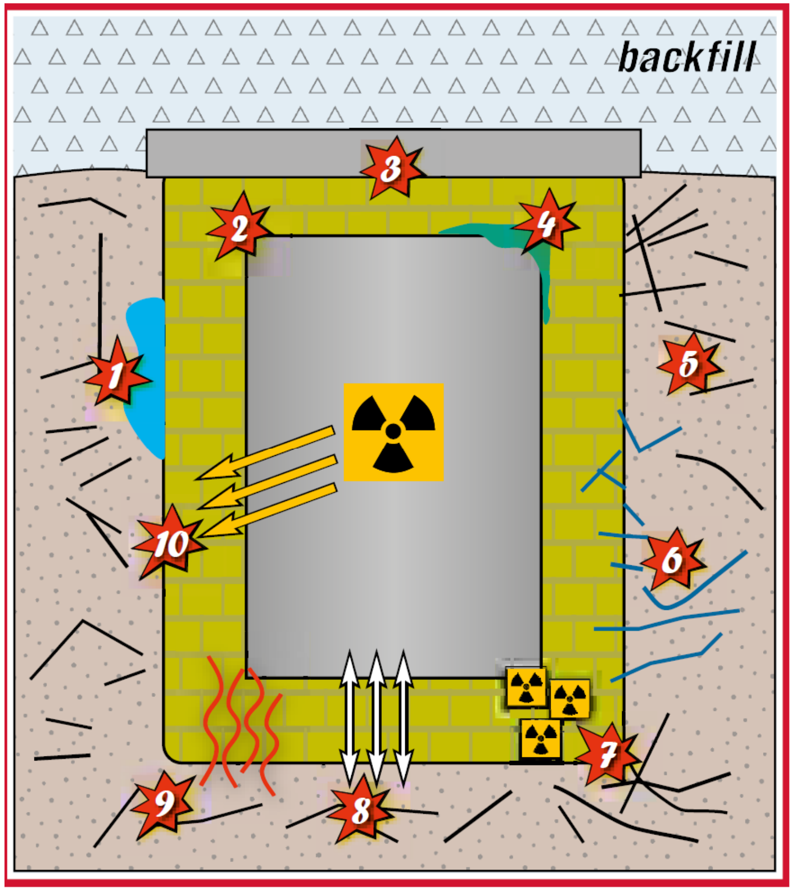
SVENSK KÄRNBRÄNSLEFÖRSÖRJNING AB / PROJEKT KÄRNBRÄNSLESÄKERHET

POSTADRESS: Kärnbränslesäkerhet, Box 5864, 102 48 Stockholm, Telefon 08-67 95 40

…and the possible problems / challenges of this new application

Discussion of parameters which can be used to distinguish suitable from less suitable HLRW bentonites

Desired / required properties of the bentonite barrier?



1 **Sealing**
(swelling capacity)

2 **Stability:** Drying (T)

3 **Stability:** Cement water

4 **Corrosion**

5 **Erosion**

6 **Stability:** Salt solutions

7 **Retention**
(radionuclide adsorption)

8 **Canister displacement**

9 **Thermal conductivity**

10 **Stability:** Radiation

Kaufhold, S. ed. (2021) Bentonites – from mine to application. – Geologisches Jahrbuch B 107, Schweizerbart, ISBN 978-3-510-96859-6. Online accessible: https://doi.org/10.1127/bentonites/9783510968596

Discussion of parameters which can be used to distinguish suitable from less suitable HLRW bentonites

Problem: Bentonite is a highly variable natural material !!

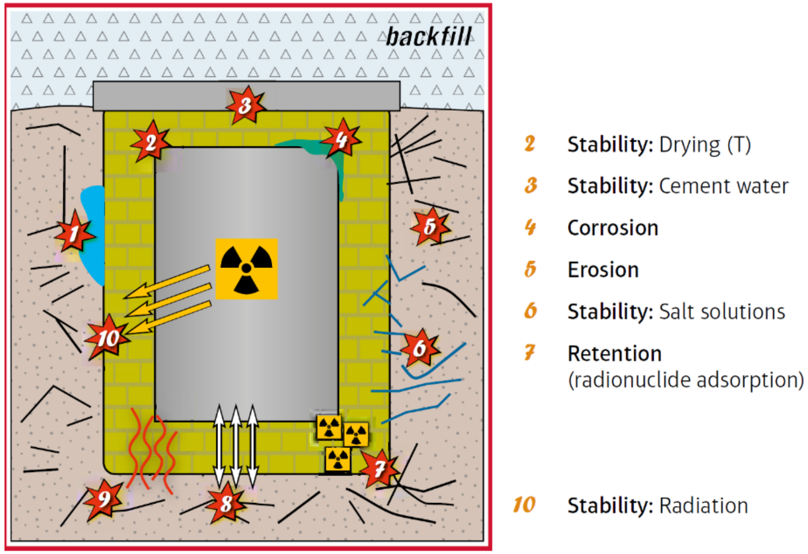
BGR:
Comparison of 38 different bentonite samples from all over the world

+ large scale tests
ABM, LOT, PTR, FEBEX, HotBent,...

Discussion of parameters which can be used to distinguish suitable from less suitable HLRW bentonites

Which bentonite is most suitable??

Some properties depend more on compaction than on type of material (no suitable criteria for bentonite selection)



Higher compaction:

higher dry density
+ lower hydraulic conductivity (sealing)

+ less canister displacement

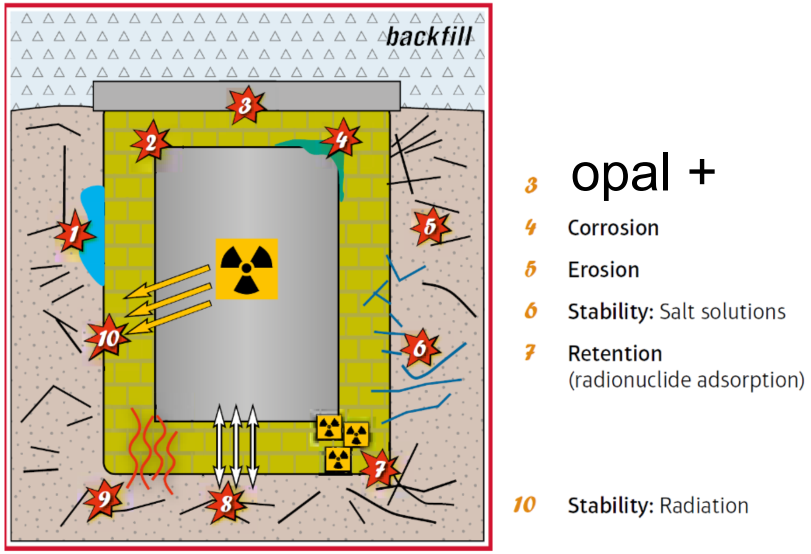
+ higher thermal conductivity

Discussion of parameters which can be used to distinguish suitable from less suitable HLRW bentonites

Stability Drying

High temperature = cation fixation = loss of swelling capacity

not specific for different bentonites
Kaufhold & Dohrmann (2010)



Stability Cement (Kaufhold et al., 2020)

Highly alkaline cement solutions dissolve bentonite

Reactive silica (opal) present in some bentonites buffers the pH

Kaufhold, S., Dohrmann, R. (2010) Effect of extensive drying on the cation exchange capacity of bentonites. – Clay Minerals, Vol. 45, No. 4, p. 441 – 448.

Kaufhold, S., Dohrmann, R., Ufer, K. (2020) Determining the extent of bentonite alteration at the bentonite/cement interface. – Applied Clay Science 186, 105446.

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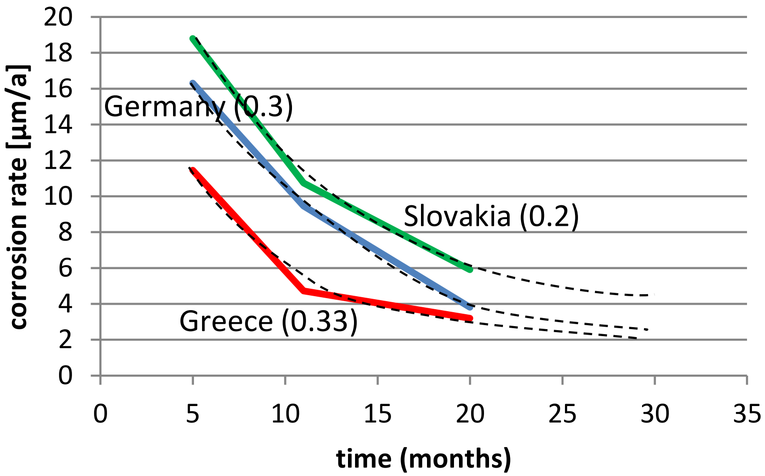
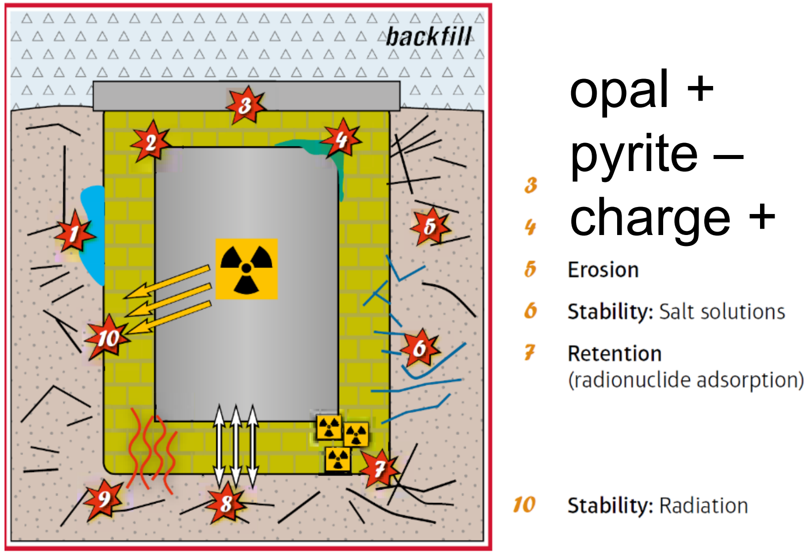
Corrosion (Fe)

Kaufhold et al. (2015)
Low charge = high corrosion



rate: 2 – 5 µm/a



opal +
pyrite –
charge +

Corrosion (Cu) Kaufhold & Dohrmann (2017):
only pyrite interacts with copper

Kaufhold, S., Sanders, D., Dohrmann, R., Hassel, A.-W. (2015) Fe corrosion in contact with bentonites. – Journal of Hazardous Materials, 285, 464–473.

Kaufhold, S., Dohrmann, R., Gröger-Trampe, J. (2017) Reaction of native copper in contact with pyrite and bentonite in anaerobic water at elevated temperature. – Corr. Eng. Sci. and Tech., 52, 349 – 358.

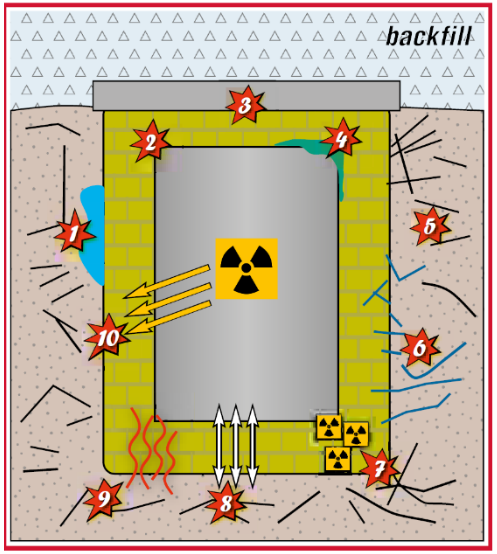
Discussion of parameters which can be used to distinguish suitable from less suitable HLRW bentonites

Erosion

Kaufhold Dohrmann (2008)
High Na-content = high erosion

Kaufhold et al. (2021)
Cation exchange is fast and cannot be avoided

=> No reasonable criteria



3
4

opal +
pyrite –
charge +

6 **Stability:** Salt solutions

7 **Retention** (radionuclide adsorption)

10 **Stability:** Radiation

Kaufhold, S., Dohrmann, R. (2008) Detachment of colloidal particles from bentonites in water. - Applied Clay Science, 39, p. 50–59.

Kaufhold, S., Dohrmann, R., Ufer, K., Svensson, D., Sellin, P. (2021) Mineralogical Analysis of Bentonite from the ABM5 Heater Experiment at Äspö Hard Rock Laboratory, Sweden. - Minerals 2021, 11, 669

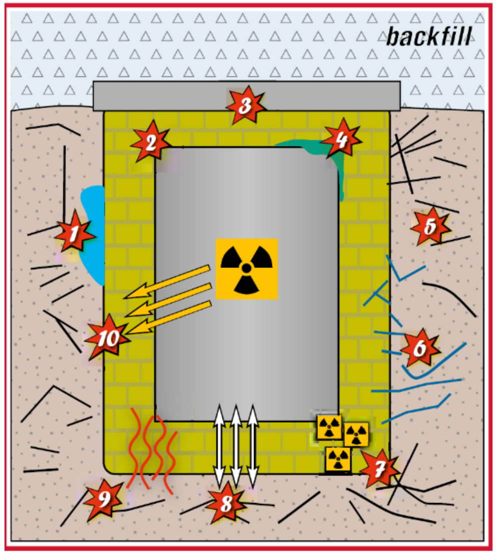
Discussion of parameters which can be used to distinguish suitable from less suitable HLRW bentonites

Stability salt solutions

Kaufhold & Dohrmann (2009, 2010), Kaufhold et al. (2019)
 Complex interaction with clay minerals – poorly understood…

Reactive (partly soluble) phases should be absent

No pyrite, no calcite, no gypsum, no organic matter



opal +
pyrite –
3 charge +
4 cal/gyp –
6 om -
7 Retention
(radionuclide adsorption)
10 Stability: Radiation

Kaufhold, S., Dohrmann, R. (2009) Stability of bentonites in salt solutions I sodium chloride. – Applied Clay Science, 45, 3, p. 171 – 177.

Kaufhold, S., Dohrmann, R. (2010) Stability of bentonites in salt solutions II. Potassium chloride solution — Initial step of illitization? – Applied Clay Science, 49, 98 – 107.

Kaufhold, S., Dohrmann, R., Degtjarev, A., Koeniger, P., Post, V. (2019) Mg and silica release in short-term dissolution tests in bentonites. - Applied Clay Science 172, 106–114.

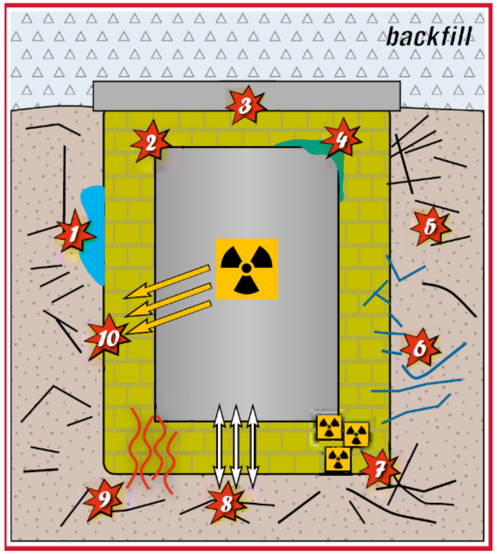
Discussion of parameters which can be used to distinguish suitable from less suitable HLRW bentonites

Radionuclide adsorption

Different radionuclides have different properties, bentonites cannot adsorb all

=> focus on the most hazardous?

I^{129} is considered one of the most hazardous – not retained by pure bentonite



opal +
pyrite –
3 charge +
4 cal/gyp –
6 om -

10 **Stability:** Radiation

Bentonite can be modified with respect to adsorption of specific radionuclides (Kaufhold et al., 2007), but no generally applicable criteria

Kaufhold, S., Pohlmann-Lortz, M., Dohrmann, R., Nüesch, R. (2007) About the possible upgrade of bentonite with respect to iodide retention capacity. - Applied Clay Science, 35, 39–46

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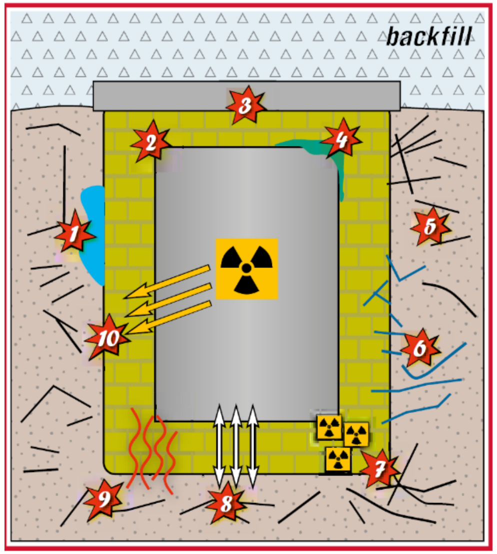
Stability against radiation

Fe rich bentonites are more affected by radiation



opal +

pyrite –

3 charge +

4 cal/gyp –

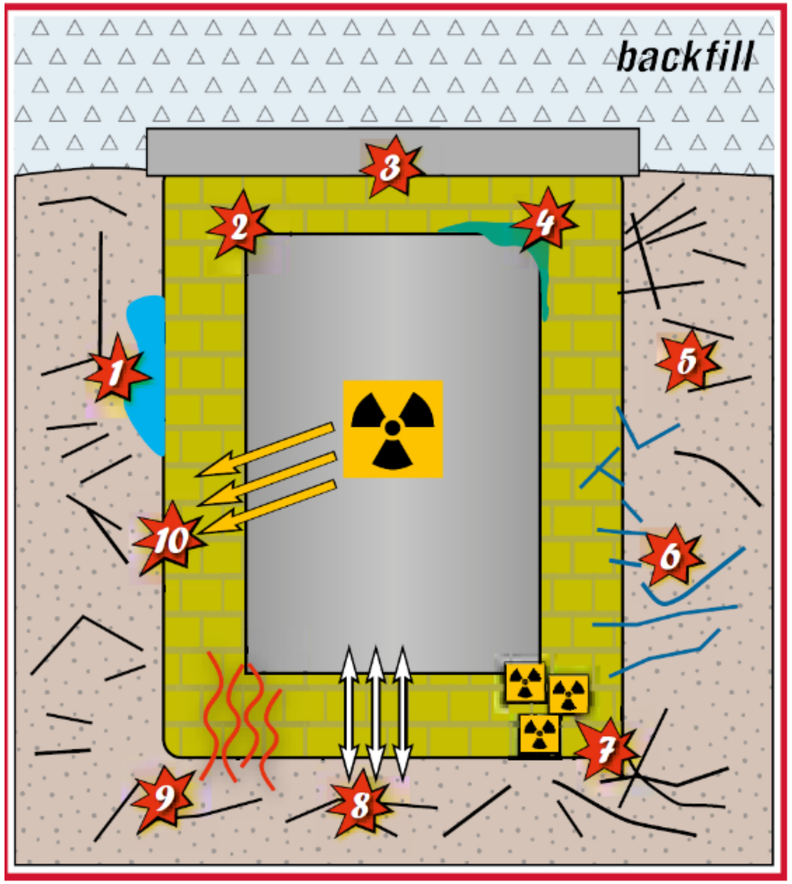
6 om -

10 Fe -

Kaufhold, S., Dohrmann, R. (2016) Distinguishing between more and less suitable bentonites for storage of high-level radioactive waste. – Clay Minerals, 51, 289-302.

Discussion of parameters which can be used to distinguish suitable from less suitable HLRW bentonites

Selection of suitable bentonites



		Positive
3	**Stability:** Cement water	presence of some opal
4	**Corrosion**	low pyrite, high charge presence of opal?carb?
6	**Stability:** Salt solutions	low pyrite, low calcite low gypsum low organic matter
10	**Stability:** Radiation	low Fe

Currently: use domestic bentonite or buy MX80 (Wyoming bentonite)

No bentonite selection decision taken yet (even not Posiva)

thanks