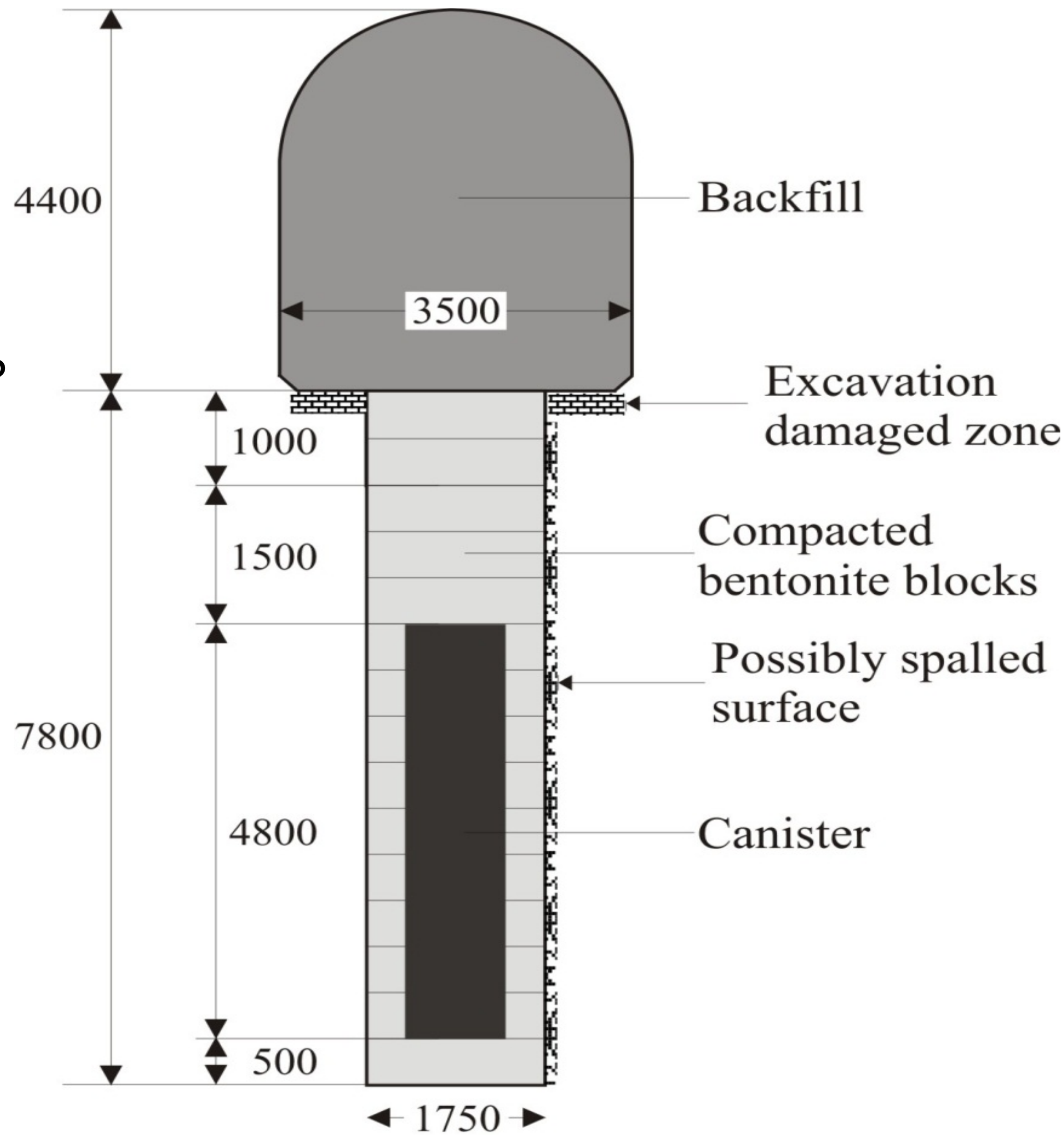
Business from technology

Radionuclide transport results
with assumed the erosion of bentonite.

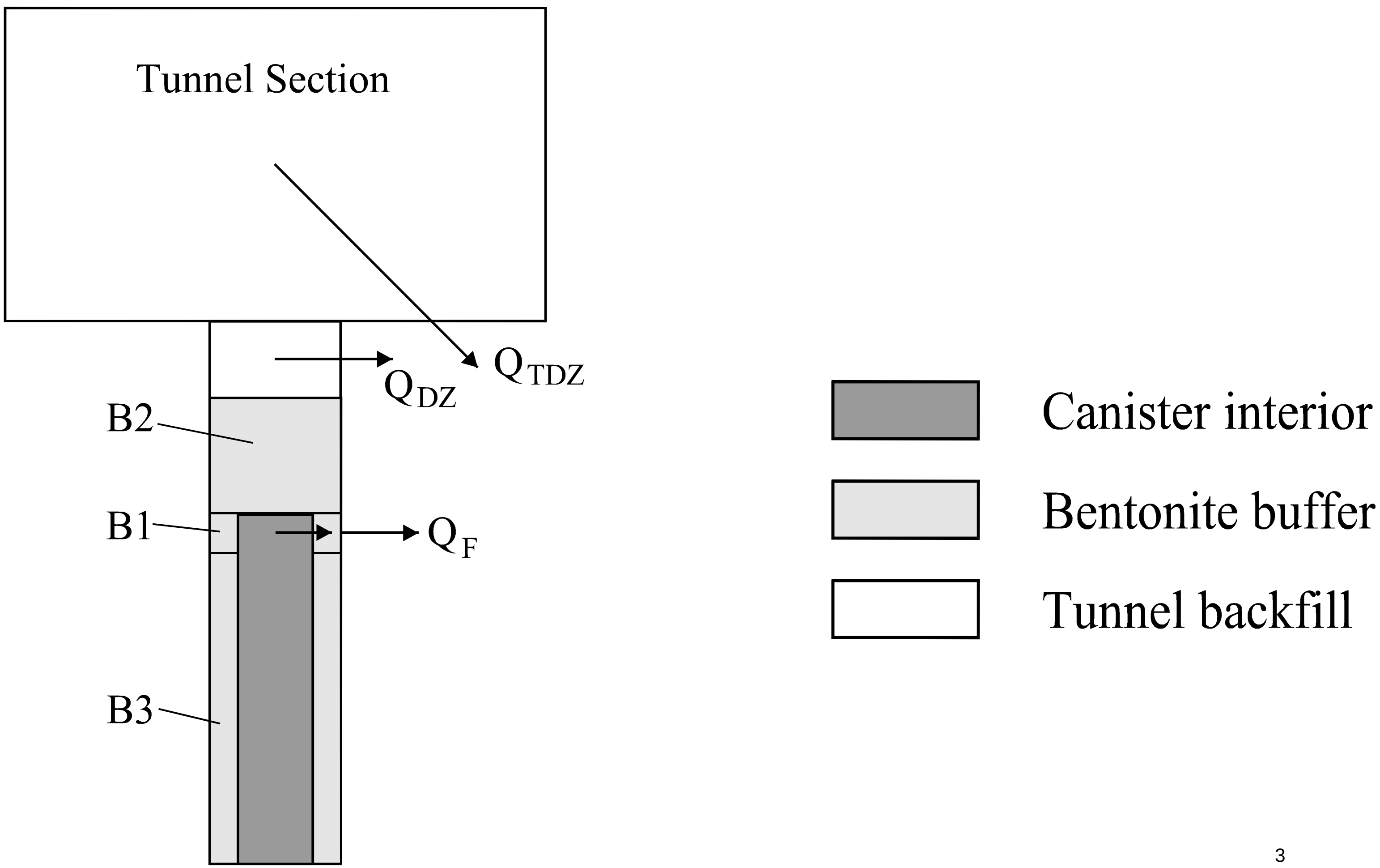
Including worst case searching (prompt by Rebecca Beard yesterday)

BELBaR workshop **6th March 2012 Henrik Nordman**

- KBS-3V hole
- Familiar to everybody ?



Old example of release routes from severely damaged canister. Only diffusion inside bentonite. Three release routes to geosphere. Effective flow Q_F to fracture opposite the damage in canister, Q_{DZ} from upper parte of deposition hole and Q_{TDZ} from tunnel to geosphere. **Only Q_F relevant in this work**



Background

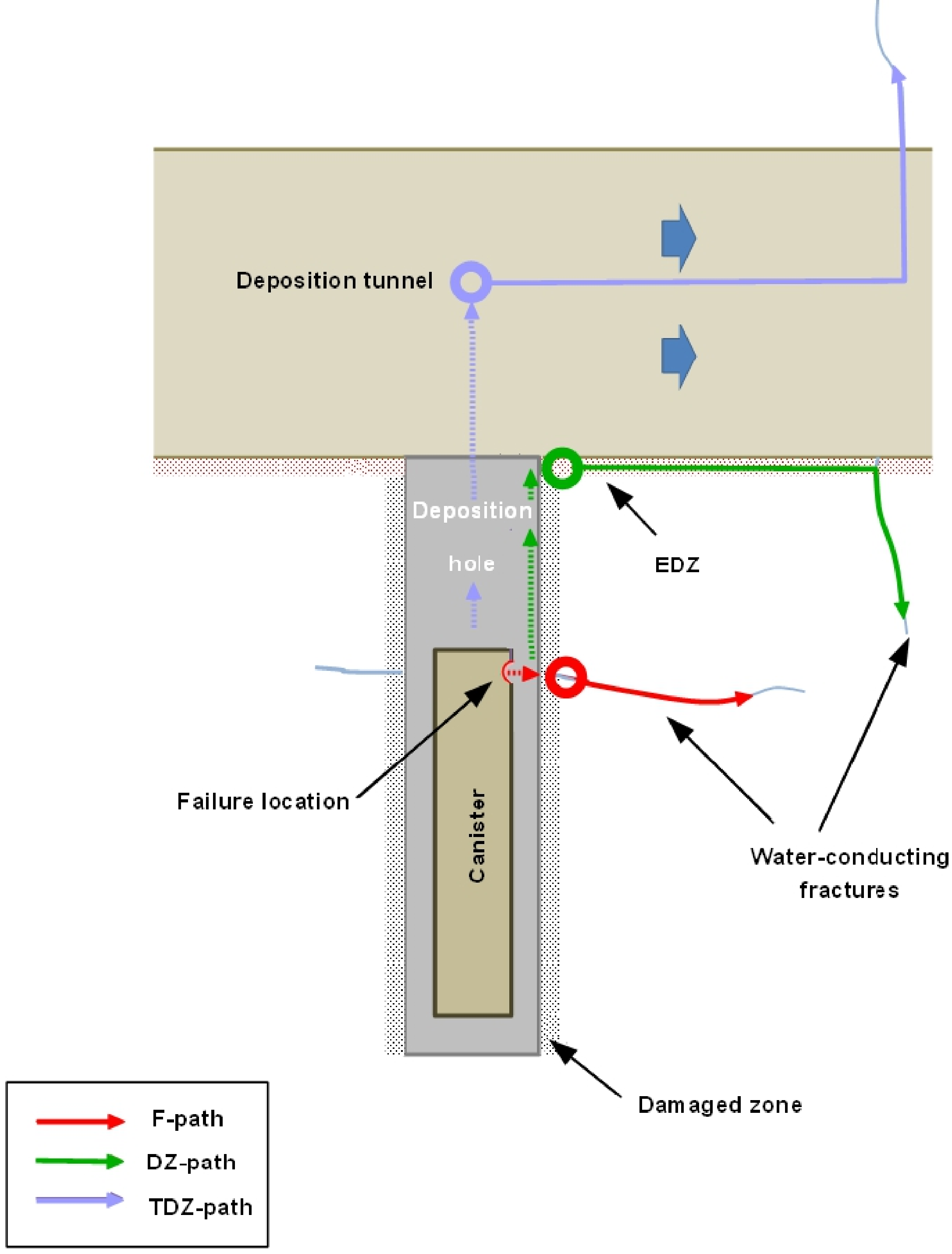
- In a normal Base Scenario it is assumed that diffusion in bentonite is a barrier and **no advection takes place in bentonite**.
- In an assumed Variant Scenario chemical erosion of the buffer and backfill takes place due to low ionic strength water penetrating to repository depth, e.g. in association with glacial retreat (chemical erosion). Glacial water period assumed to be 333 years long.
- Significant buffer erosion is considered unlikely, but cannot currently be excluded in at least some of the deposition holes.
- The degraded buffer has a reduced capacity to retain radionuclides released subsequent to canister failure and also act as a source of bentonite colloids.
- Advective conditions may prevail in a ring of partly eroded
- Colloids can sorb radionuclides and transport them relatively rapidly into the geosphere during glacial cycle of 333 years.

Chain of cases for severely defected canister and variable flow Q_F to fracture (route F) in all cases . **Added feature in bold blue**

- RS case = Rock shear with moderate high flow. Diffusion barrier in bentonite. No colloid release. Brackish water in bentonite
- RShigh case =Rock shear case with **high flow .** Diffusion barrier in bentonite. No colloid release. Brackish water in bentonite
- ERR case = Eroded bentonite with high flow. **Advective ring near** fracture. No colloid release. Brackish water in bentonite
- ERRcol case = Eroded bentonite with high flow. Advective ring near fracture. **COLLOID RELEASE and glacial water chemistry at 333 years cycle. Bentonite colloid concentration 0.051 kg/m^3**
- ERRcolhigh case = Eroded bentonite with high flow. Advective ring near fracture. COLLOID RELEASE and glacial water chemistry at 333 years cycle. Bentonite colloid concentration **0.51 kg/m^3**
- **Fuel degradation rate ?? 10 million years or 500 000 years ? Combined with lower flow e.g.**

Three potential near field paths when bentonite no eroded. *F*, *DZ* and *TDZ*, are **repeated again in the figure** next slide. F path; **main release F path with flow rate Q_F to geosphere**.

- the F-path leads from the canister, through the buffer and the deposition hole damaged zone to a host-rock fracture intersecting a deposition hole;
- the DZ-path leads from the canister, through the buffer (and/or the deposition hole damaged zone) to the deposition tunnel EDZ, and thence to a host-rock fracture intersecting the EDZ; and
- the TDZ-path leads from the canister, through the buffer to the deposition tunnel backfill, and thence to a host-rock fracture intersecting the deposition tunnel.
- **Bentonite is a diffusion barrier in a Base Case. No advection in it.**

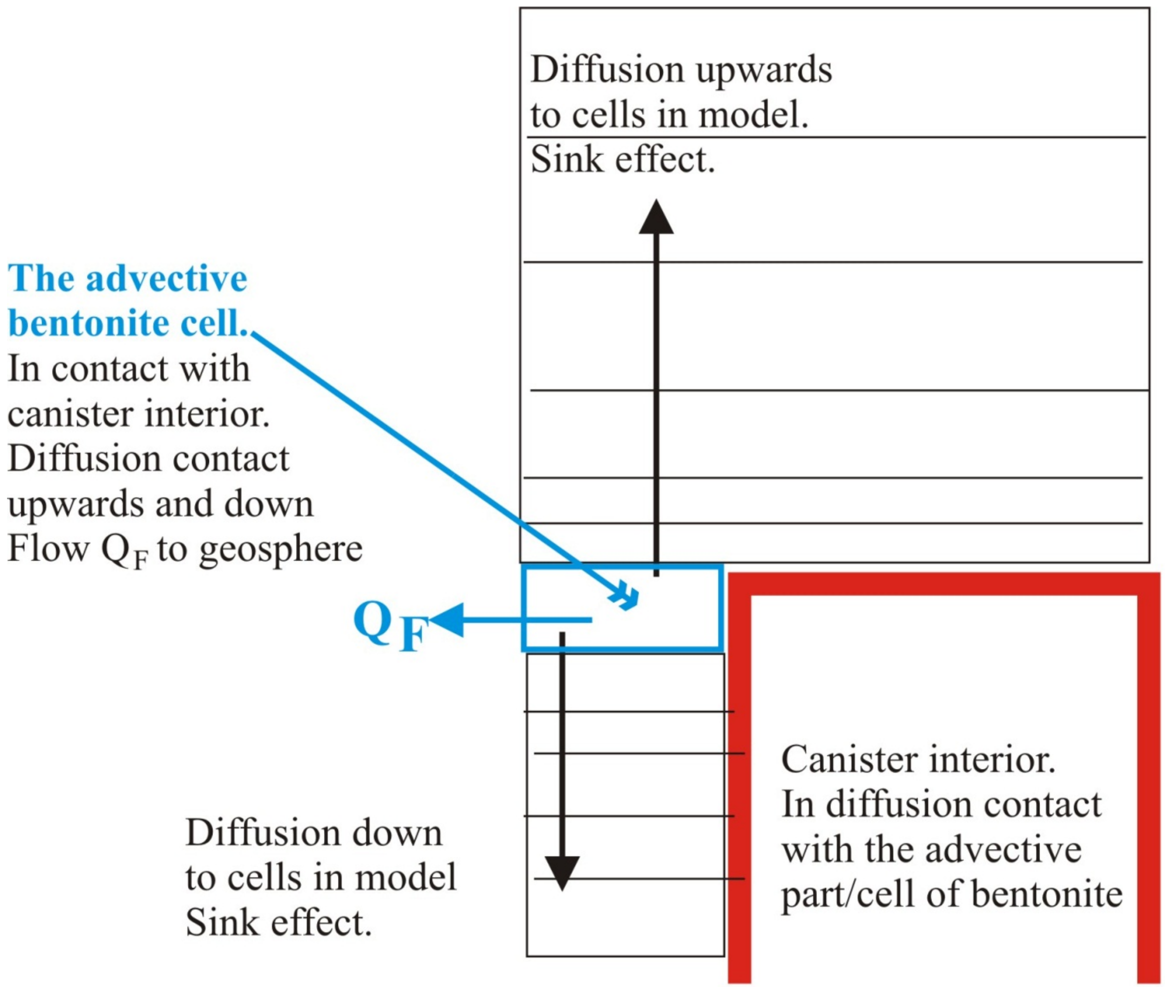


Deposition tunnel
Deposition
hole
EDZ
Canister
Failure location
Water-conducting
fractures
Damaged zone
F-path
DZ-path
TDZ-path

Assumptions for defected canister and eroded bentonite. I still like explainable paradoxes after 20 years.

- Bentonite becomes advective when 1200 kg has eroded. E.g four 333 long years cycles with flow of 1 m^3/yr and a colloid concentration of 1 kg/m^3 during the 4 cycles => 1332 kg eroded.
- Canister fails (or has failed due to rock shear) and water has access to the fuel.
- Advective conditions are assumed in a ring of partly eroded 35 cm × 35 cm eroded bentonite ring.
- The eroded amount of bentonite is replaced from bentonite both above and below so there is 848 kg bentonite in the ring.
- The assumptions include several 333 year long glacial water cycles with high flow to geosphere and an enhanced release of radionuclides during the cycle as colloids.
- Figure on next slide presents the GoldSim model/grid for eroded bentonite

Eroded bentonite



The release rate from near field=J as colloids is as in GoldSim model. **Sorbtion of nuclides on bentonite, bentonite + nuclides released as colloids. Simple ?**

- J= NUCINV·flowselect·collrate·Q_F/848.0 , (1)

where

NUCINV, is the nuclide inventory in the advective volume

848.0, is the mass of bentonite in the advective volume (848 kg)

collrate, is the colloid concentration in water during the cycle (e.g. 0.51 kg/m^3)

Q_F, is the high flow rate to geosphere from advective volume (m^3/yr)

flowselect, is a variable which is switched to value 1 during the glacial cycle.

- P.S. Rate J should be corrected with factor (R-1)/R, but effect negligible.
  R= retardation factor in bentonite.

Other data

- Moderate high flow means that flow Q_F to geosphere is 0.1 m^3/yr at interglacial phase and 1 m^3/yr at glacial cycle.
- High flow means that Q_F is 1.75 m^3/yr at interglacial phase and 17.5 m^3/yr at glacial cycle. High gradient at glacial cycle or whatever the reason ?
- There are about 20 glacial meltwater cycles during calculation
- period of 1 million years.
- Release starts always at 155 000 years in all cases. Also in RS (rock shear) cases, where bentonite has not eroded => diffusion barrier.
- Applied Kd values , solubility limiys etc. are not be presented here.

Results summary as introduction to next slides. All tables near field.

- Release starts at 155 000 years in all cases.
- The results are shown mostly on some interesting or relevant nuclides
- The most important thing is, if bentonite is advective or not. In RS cases bentonite acts as diffusion barrier
- The maximum is always at the time of 333 years long higher flow period. The flow increases from 0.1 to 1 m^3/yr in RS low flow case. In other cases flow inreases from 1.75 to 17.5 m^3/yr. Quite huge flows by the way based on…..?

RS cases with low and high flow and an advective eroded case with high flow. All with glacial cycle, brackish water and no nuclide release with colloids. Funny some nuclides. RS high lower release rate than RS low. Can be explained N.B maximums at glacial cycles when 10 times higher flow prevail. **FIRST CONCLUSION. Advective 35 cm x 35 cm or not, most important** Huge increase in release rate in ERR, high flow.

Nuclide	RS, low flow		RS, high flow		ERR, high flow	
	t_{max} (yr)	Bq/yr	t_{max} (yr)	t_{max} (yr)	t_{max} (yr)	Bq/yr
Cl-36	1.55E+05	2.52E+05	1.55E+05	2.54E+05	1.55E+05	6.13E+07
Cs-135	1.55E+05	7.73E+06	1.55E+05	1.08E+07	1.55E+05	4.60E+07
Pu242	9.90E+05	2737.5	9.90E+05	1383.1	2.70E+05	2.08E+05
Ra-226	5.85E+05	4.94E+4	5.85E+05	4.71E+4	4.65E+05	4.62E+05
Th-229	9.90E+05	196.04	9.90E+05	74.166	9.90E+05	1.82E+06
Th230	5.85E+05	780.55	5.85E+05	471.49	4.65E+05	2.92E+05

Erosion bentonite advective. Flow higher 333 years cycles.
First case brackish water no colloid release (last case in previous slide). And two colloid cases 0.051 and 0.51 kg/m^3 with glacial waters higher flow periods.
Ra-226, mystery, solubility limit oscillating ?
Pu-242 an th has the high on bentonite/colloid, so the release rate with colloid concentration 0.51 is high.

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Nuclide	ERR no coll		ERR coll 0.051 kg/m^3		ERR coll 0.51 kg/m^3	
	t_{max} (yr)	t_{max} (yr)	t_{max} (yr)	t_{max} (yr)	t_{max} (yr)	Bq/yr
Cl-36	1.55E+05	6.13E+07	1.55E+05	6.33E+07	1.55E+05	6.33E+07
Cs-135	1.55E+05	4.60E+07	1.55E+05	4.36E+07	1.55E+05	4.38E+07
Pu242	2.70E+05	2.08E+05	2.25E+05	9.94E+05	2.25E+05	7.43E+06
Ra-226	4.65E+05	4.62E+05	5.85E+05	9.12E+05	5.85E+05	4.57E+05
Th-229	9.90E+05	1.82E+06	9.90E+05	6.68E+06	9.90E+05	3.97E+07
Th230	4.65E+05	2.92E+05	4.65E+05	1.10E+06	4.65E+05	6.63E+06

Next variants for advective eroded bentonite

- Change the degradation rate of uranium dioxide matrix from 1E-7/yr to 2E-6 /yr.
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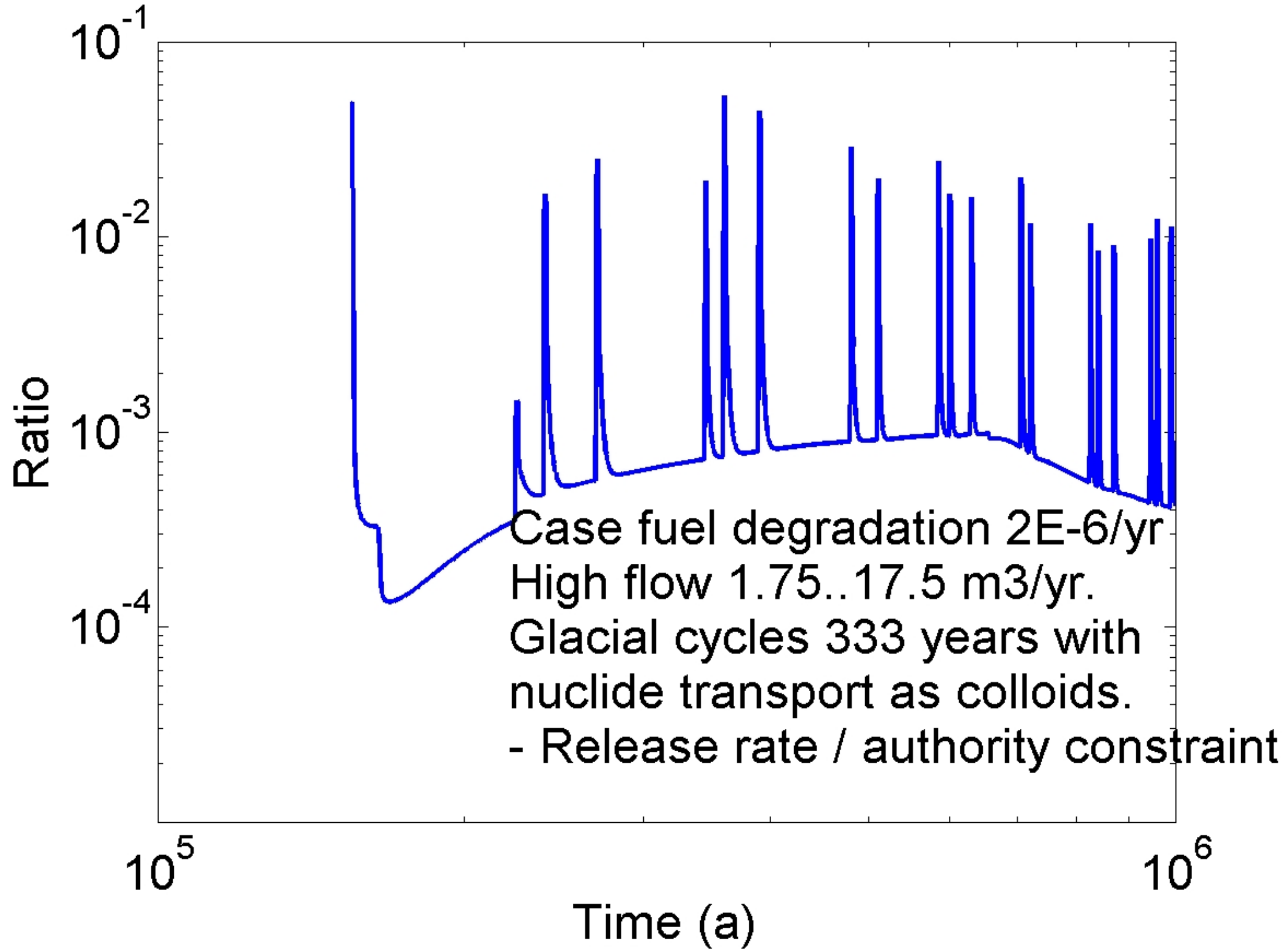
High fuel degradation 20 * => Th-230 and Th-232 increase and thus dominate the solubility limit ??? => Th-229 decrease in case "ERRfuel no col" compared to compared to case with lower fuel degradation rate "ERR no coll"

Nuclide	ERR no coll		ERRfuel no coll		ERRfuel 0.051 kg/m^3	
	t_{max} (yr)	t_{max} (yr)	t_{max} (yr)	t_{max} (yr)	t_{max} (yr)	Bq/yr
Cl-36	1.55E+05	6.13E+07	1.55E+05	6.13E+07	1.55E+05	6.33E+07
Cs-135	1.55E+05	4.60E+07	1.55E+05	4.61E+07	1.55E+05	4.37E+07
Pu242	2.70E+05	2.08E+05	9.45E+05	1.11E+06	5.85E+05	5.27E+06
Ra-226	4.65E+05	4.62E+05	2.25E+05	9.69E+06	2.25E+05	5.27E+07
Th-229	9.90E+05	1.82E+06	2.25E+05	8.35E+05	2.25E+05	3.15E+06
Th230	4.65E+05	2.92E+05	2.25E+05	2.12E+06	2.25E+05	8.06E+06

Right most case ERRfuel with colloid concentration 0.051 is presented as figure on next slide **after a geosphere transport**. Interglacial = WL/Q 50000 m/yr and glacial 5000.

Ratio to authority constraints.

ERRfuel with colloid concentration 0.051**after a geosphere transport**.
Interglacial = WL/Q 50000 m/yr and glacial 5000 m/yr.
N.B. If WL/Q ~0 then Nb-93m daughter of Zr-93 almost breaks the limit.



Finally a risk

- 23 GBq U-238 + daughters precipitated in a deposition hole. (excess of U-234 at most a factor of ~10)
- Produces yearly 0.01 GBq Ra-226 (in 1 million years 10 000 GBq:s of Ra-226)
- YVL limit for yearly Ra-226 release is 0.03 GBq/yr
- Geosphere parameters for Ra-226 may be critical. Especially if earthquake damages several canisters in a tunnel.

First case = “ERRfuel lflow no coll“ low flow 0.1 m^3/yr = lflow compared to high hflow 1.75 m^3/yr

Nuclide	ERRfuel lflow no coll		ERRfuel hflow no coll		ERRfuel hflow co 0.051	
	t_{max} (yr)	t_{max} (yr)	t_{max} (yr)	t_{max} (yr)	t_{max} (yr)	Bq/yr
Cl-36	1.55E+05	1.14E+07	1.55E+05	6.13E+07	1.55E+05	6.33E+07
Cs-135	1.55E+05	2.67E+07	1.55E+05	4.61E+07	1.55E+05	4.37E+07
Pu242	9.45E+05	1.57E+05	9.45E+05	1.11E+06	5.85E+05	5.27E+06
Ra-226	2.70E+05	5.54E+05	2.25E+05	9.69E+06	2.25E+05	5.27E+07
Th-229	2.25E+05	5.26E+04	2.25E+05	8.35E+05	2.25E+05	3.15E+06
Th230	2.70E+05	2.41E+05	2.25E+05	2.12E+06	2.25E+05	8.06E+06