



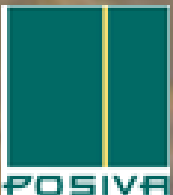
Chemical erosion of bentonite: a challenge or a threat?

Heini Reijonen & Nuria Marcos, Saanio & Riekkola Oy

BELBaR 12.-13.10.2015 Karlsruhe, Germany

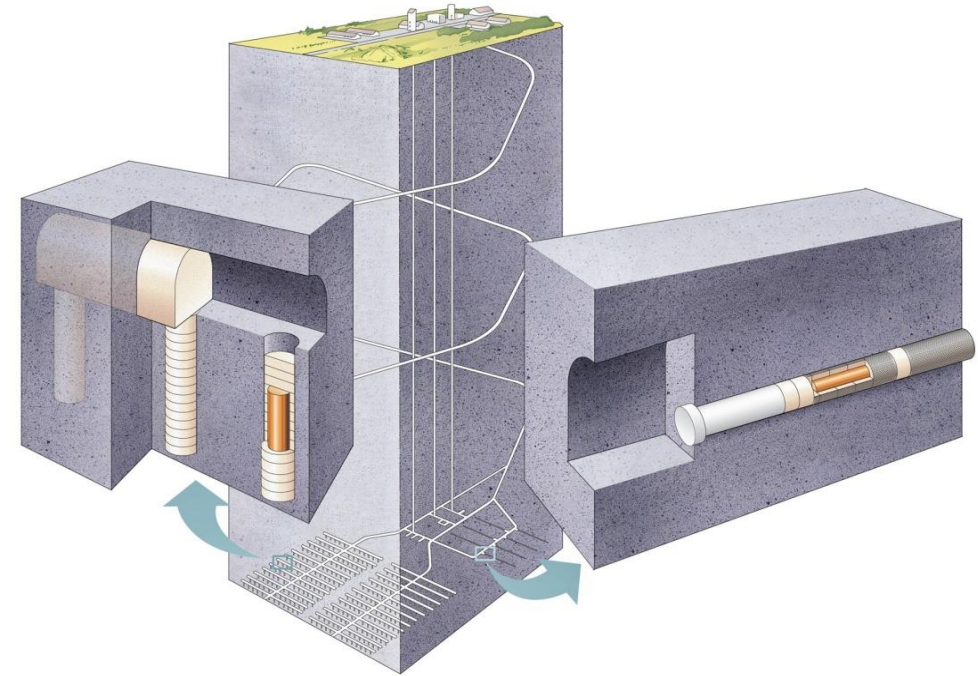


Photo: Schatz et al. (2013)

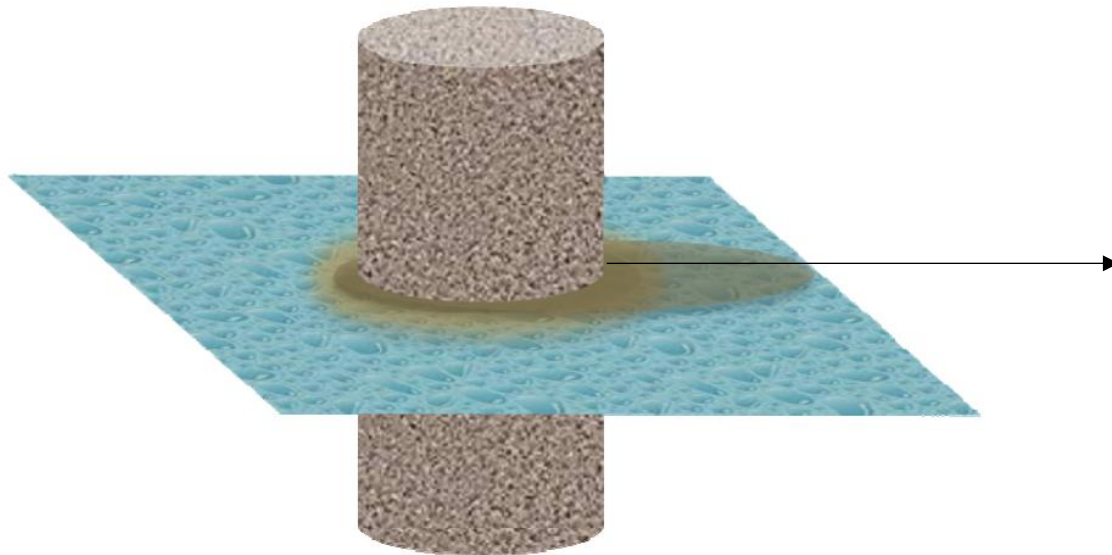


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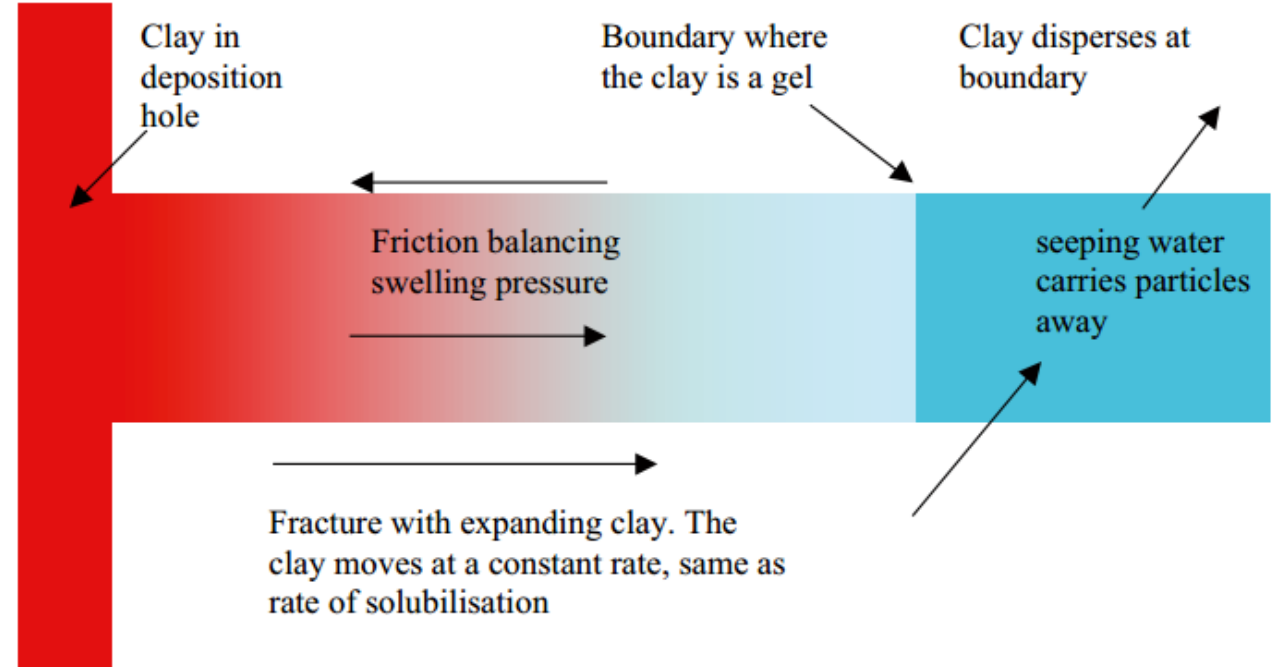
- Background – The threat
 - Basis for the FEP
 - Assessing the impact
- Natural analogues for chemical erosion?
 - Development of dilute groundwater conditions
 - Erosion of bentonite
- The challenge – questions // Conclusions



Basis for FEP – chemical erosion



Posiva (2013a)



Schematic illustration of buffer extrusion and erosion in an intersecting, transmissive fracture
From Liu & Neretnieks (2006)



Chemical erosion - understanding

- Approach from two perspectives:
 - 1) Development of the groundwater conditions at repository depth at Olkiluoto site (or any other site)
 - 2) The process of chemical erosion
 - Laboratory experiments and modelling
 - Limited amount of experiments
 - Modelling capabilities limited
 - See e.g. Schatz et al. (2013)

General understanding is that bentonite erosion does not occur when total charge equivalent of cations in groundwater is higher than 4mM, which is reflected in the long-term safety requirements (e.g. SKB 2011, Posiva 2013a).

Assessing the impact (TURVA-2012 safety case)

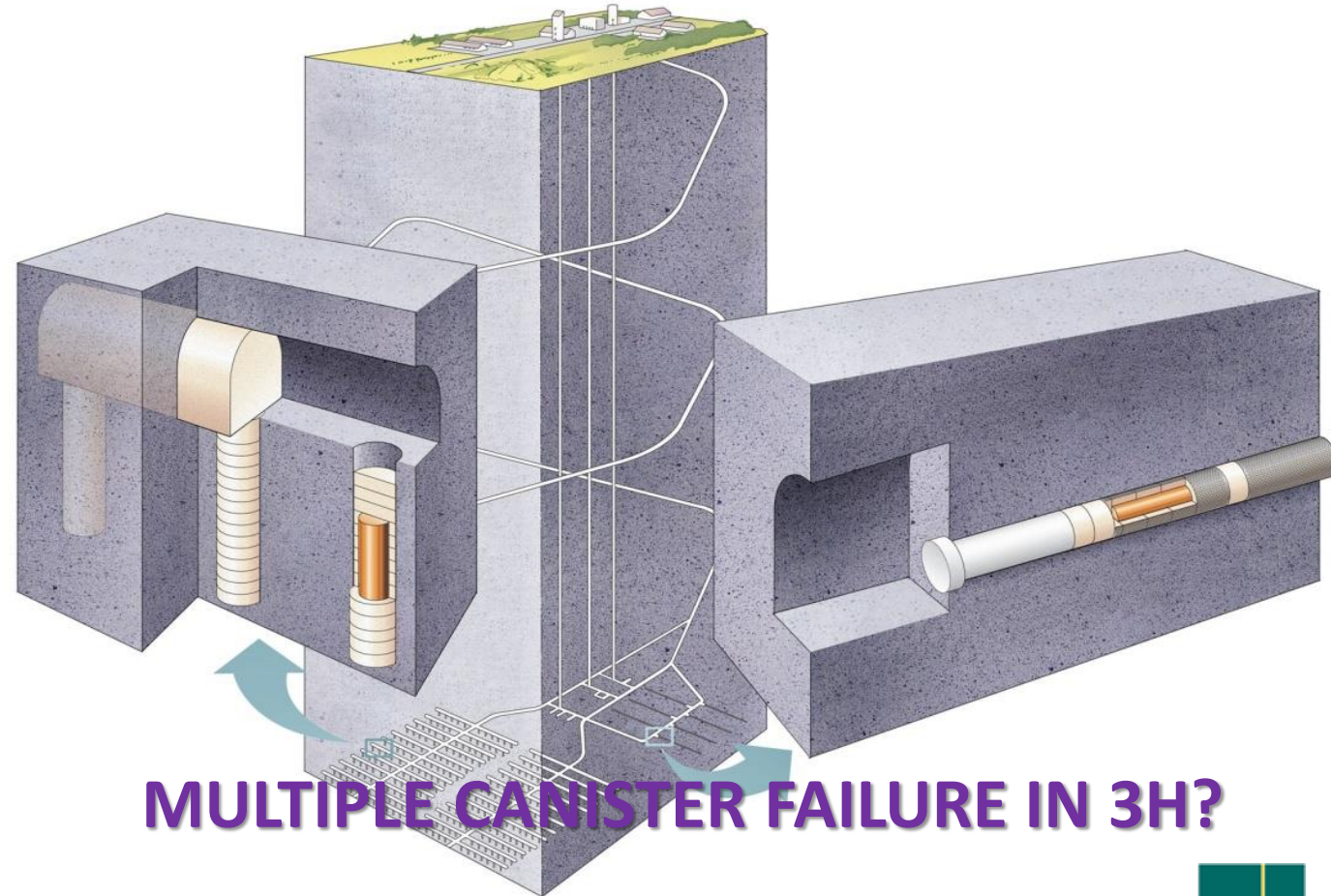
PERFORMANCE ASSESSMENT (3V):

- Modelling of the groundwater evolution
- Modelling of the bentonite erosion

uncertainties



- FEP was assessed in radionuclide release scenarios due to these uncertainties (Posiva 2013b)



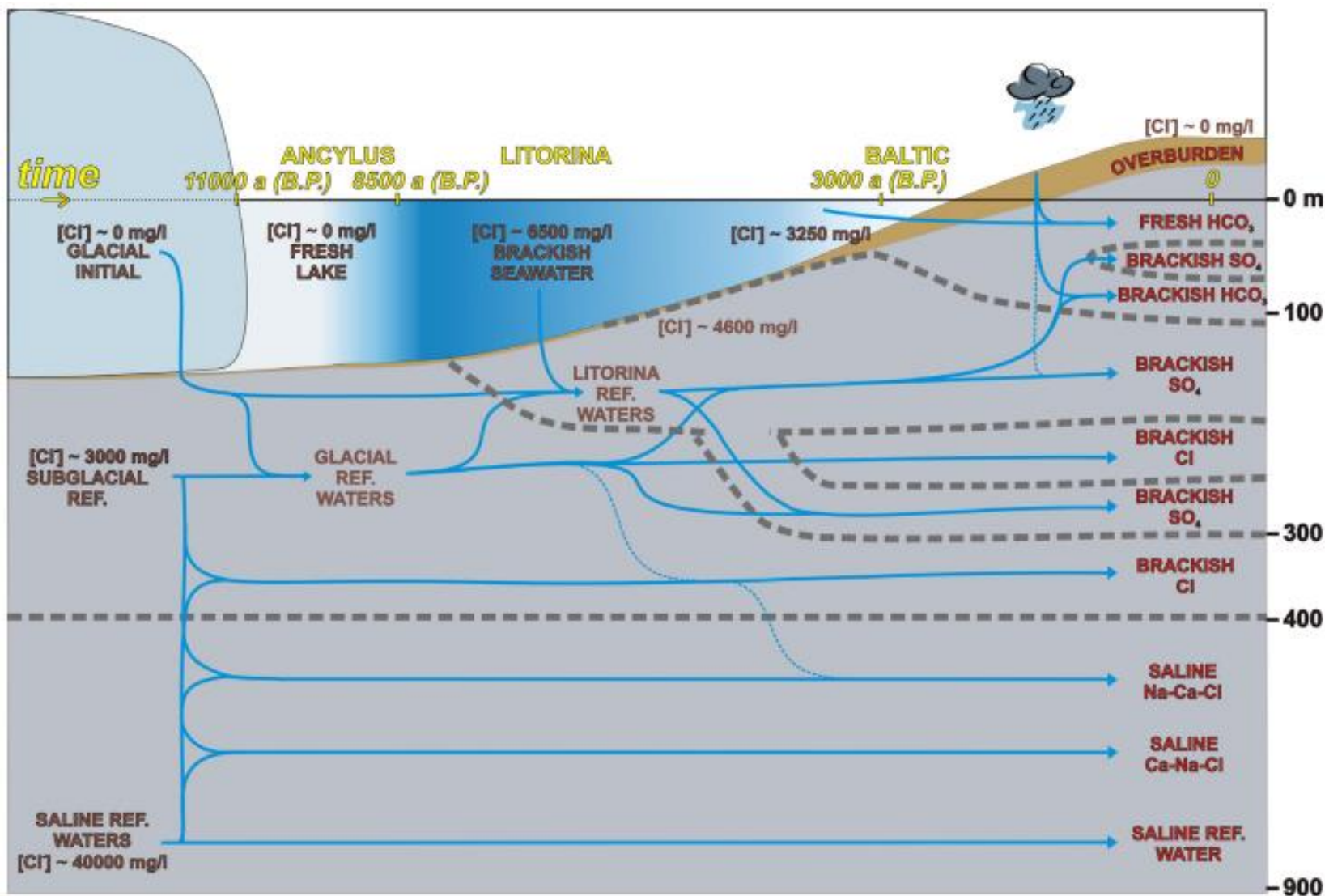


Natural analogues

FOR

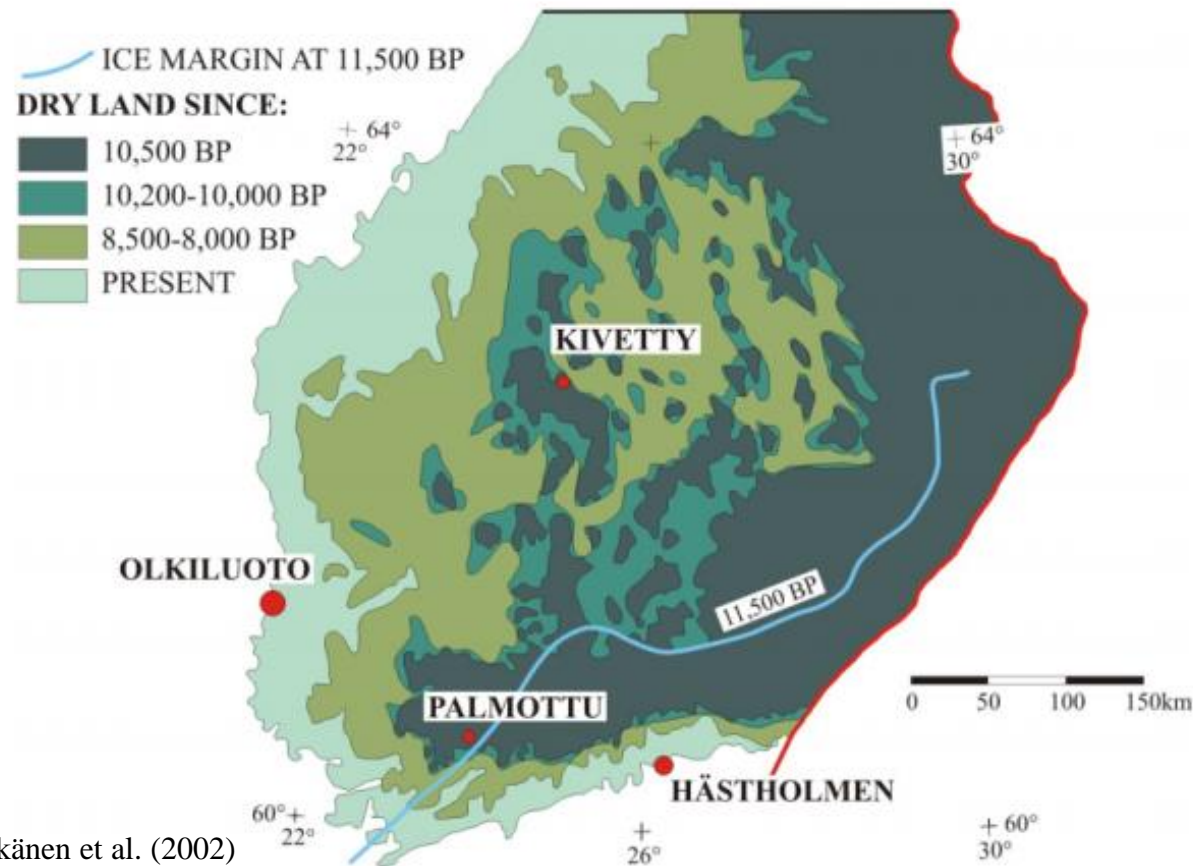
1. Development of dilute conditions in the host rock
2. Erosion of bentonite?

I-Dilute groundwater conditions – at the site





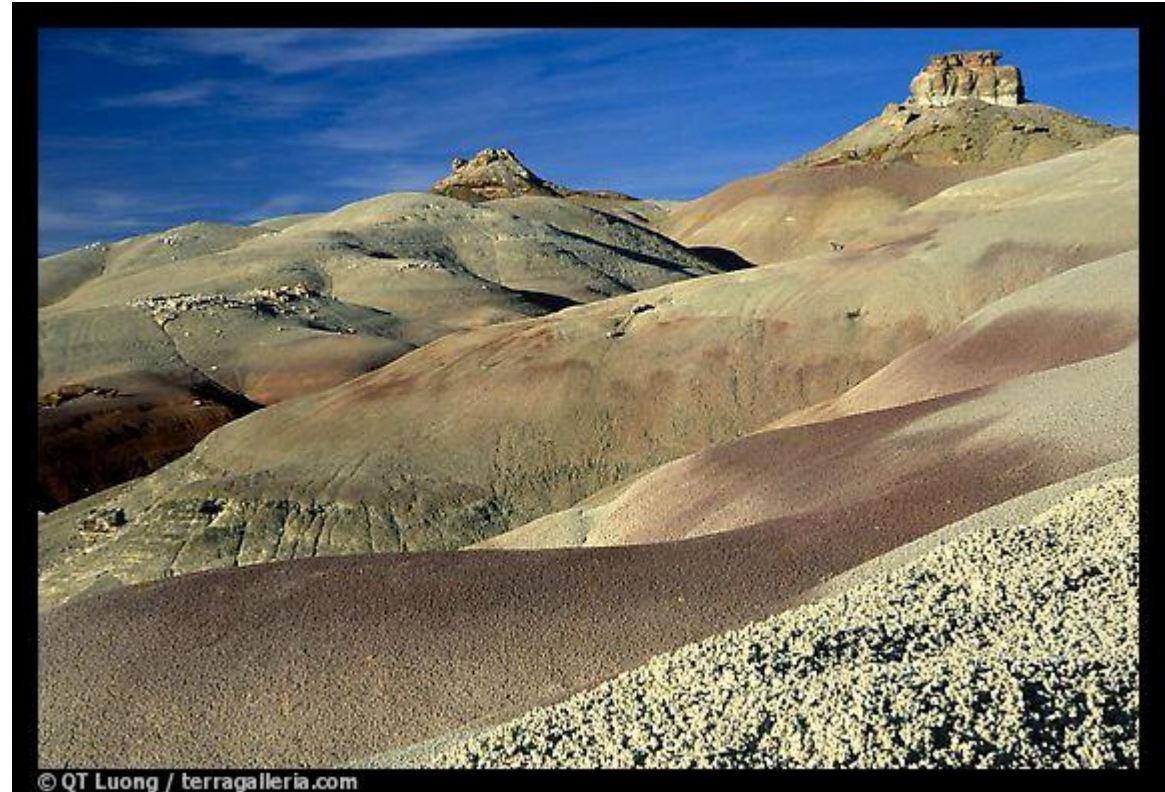
II-Dilute groundwater conditions – other site(s)



Pitkänen et al. (2002)

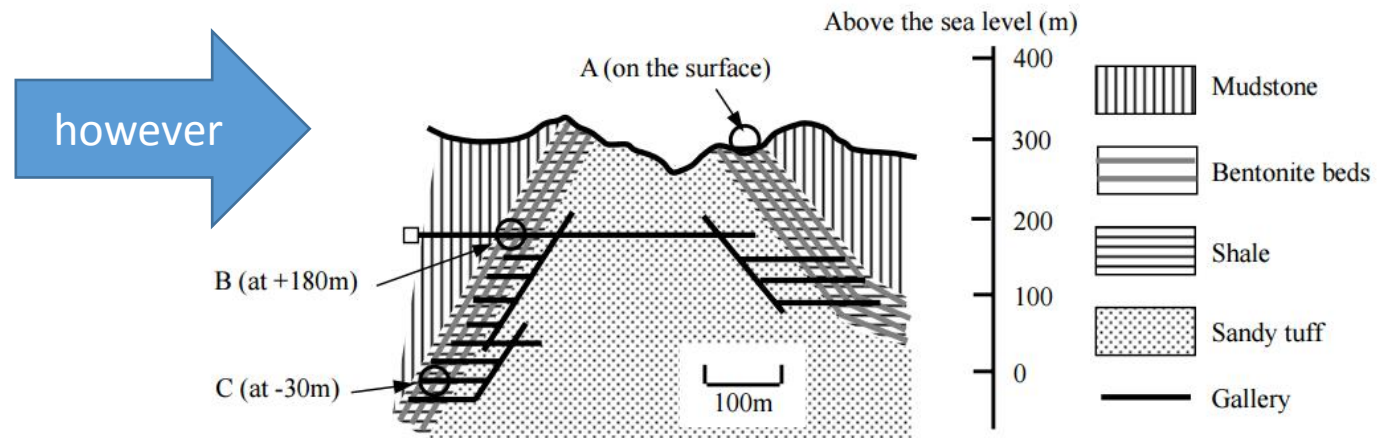
I-Natural analogues for erosion of bentonite

Fetching far



Bentonite deposits

- Erosion of bentonite deposits by fresh water
- Limitations: multiple erosional mechanisms, e.g. weathering, drafting.



Example of a situation where natural bentonite erosion could be studied. Schematic cross section through the Tsukinuno bentonite mine, northern Japan. Locations of sampled groundwater (A - C) and their depths (above the sea level) are indicated. Kuno et al. (2002).

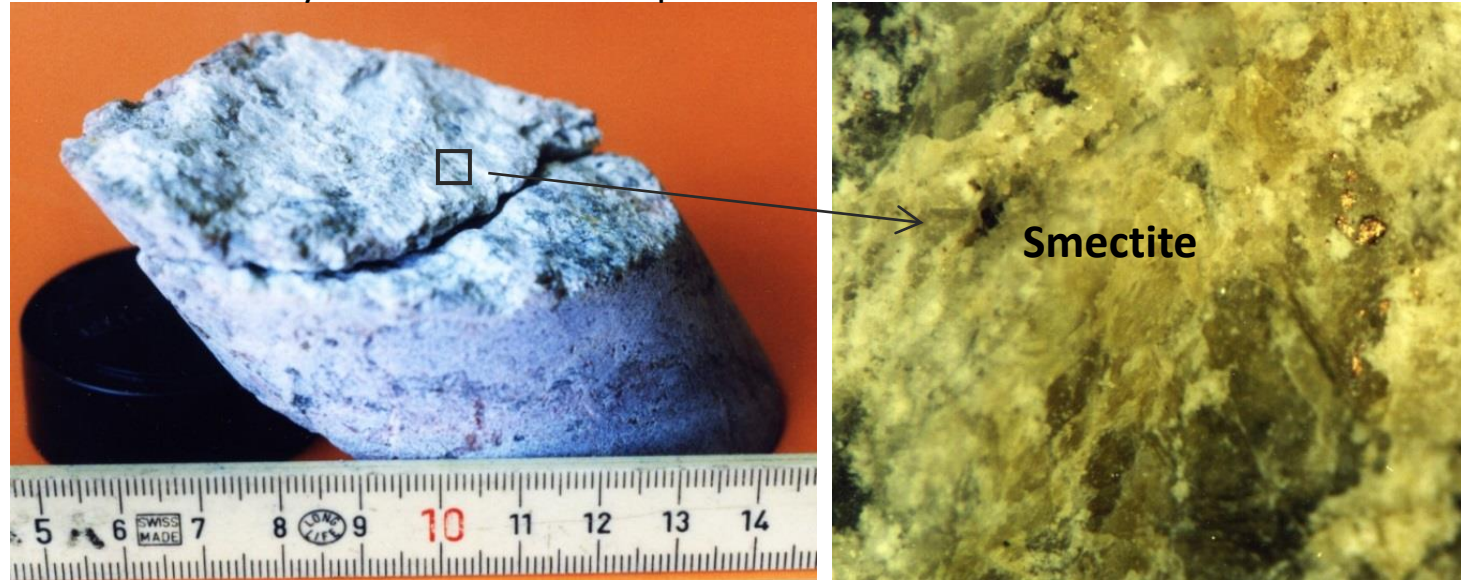


II-Natural analogues for erosion of bentonite – Coming closer...



Hyrkkölä site in Finland

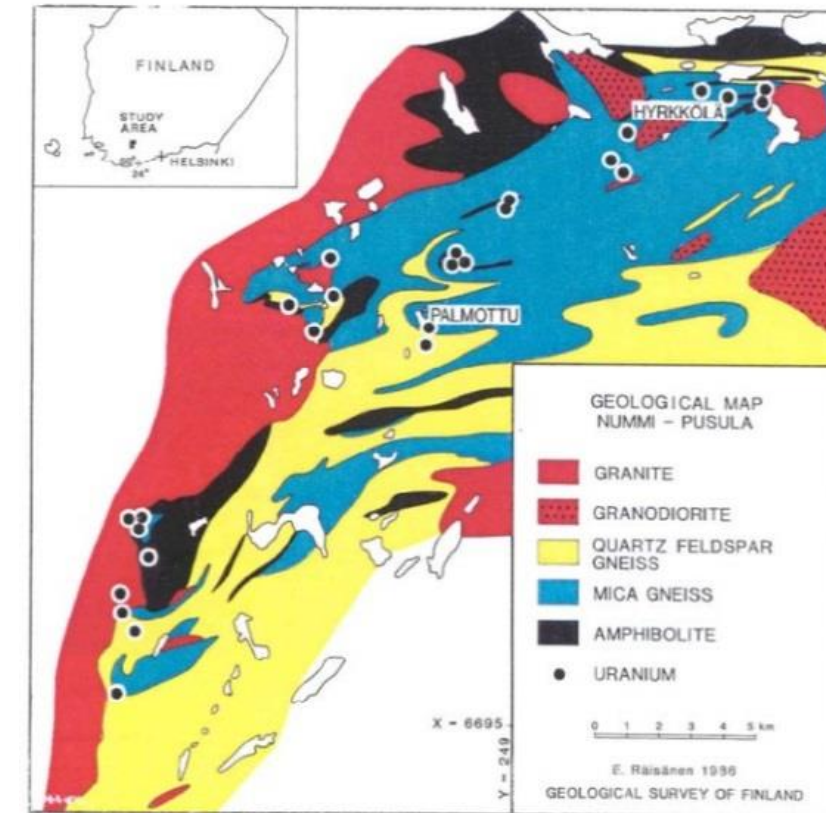
Drill core from Hyrkkölä at c. 80 m depth:



Marcos (2002)

Current groundwater composition (mgL⁻¹) at this depth:

pH	TDS	Ca	Mg	Na	K	Si	Fe	U	Cl	SO ₄	HCO ₃	NO ₃	O ₂
6.6	116	14.4	4.3	7.1	2.8	5.9	0.05	0.093	3.8	10	57	10	4



Marcos and Ahonen (1999)



Päijänne tunnel

Providing drinking water to Helsinki area since 1982, tunnel depth between 30 – 130 m.

During pre-construction characterization, montmorillonite was found as fractures filling – no or only very thin grouting or reinforcement carried out

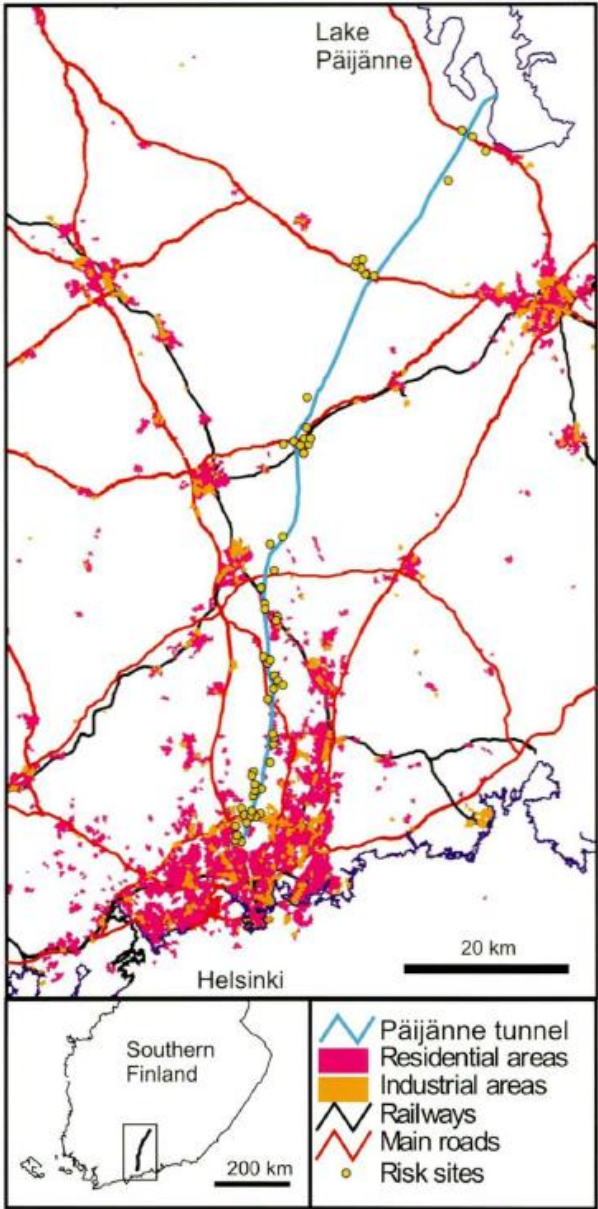
1997 cave-in due to montmorillonite swelling and erosion; rock fall at 60 m depth along 20 m distance.

Flow rate 2.9 m³/s

pH	TDS mg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Si mg/L	Fe µg/L	Al µg/L
7.2/8.5	116	18	1.7	5.2	1.3	5.9	77	6

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Lipponen (2002)



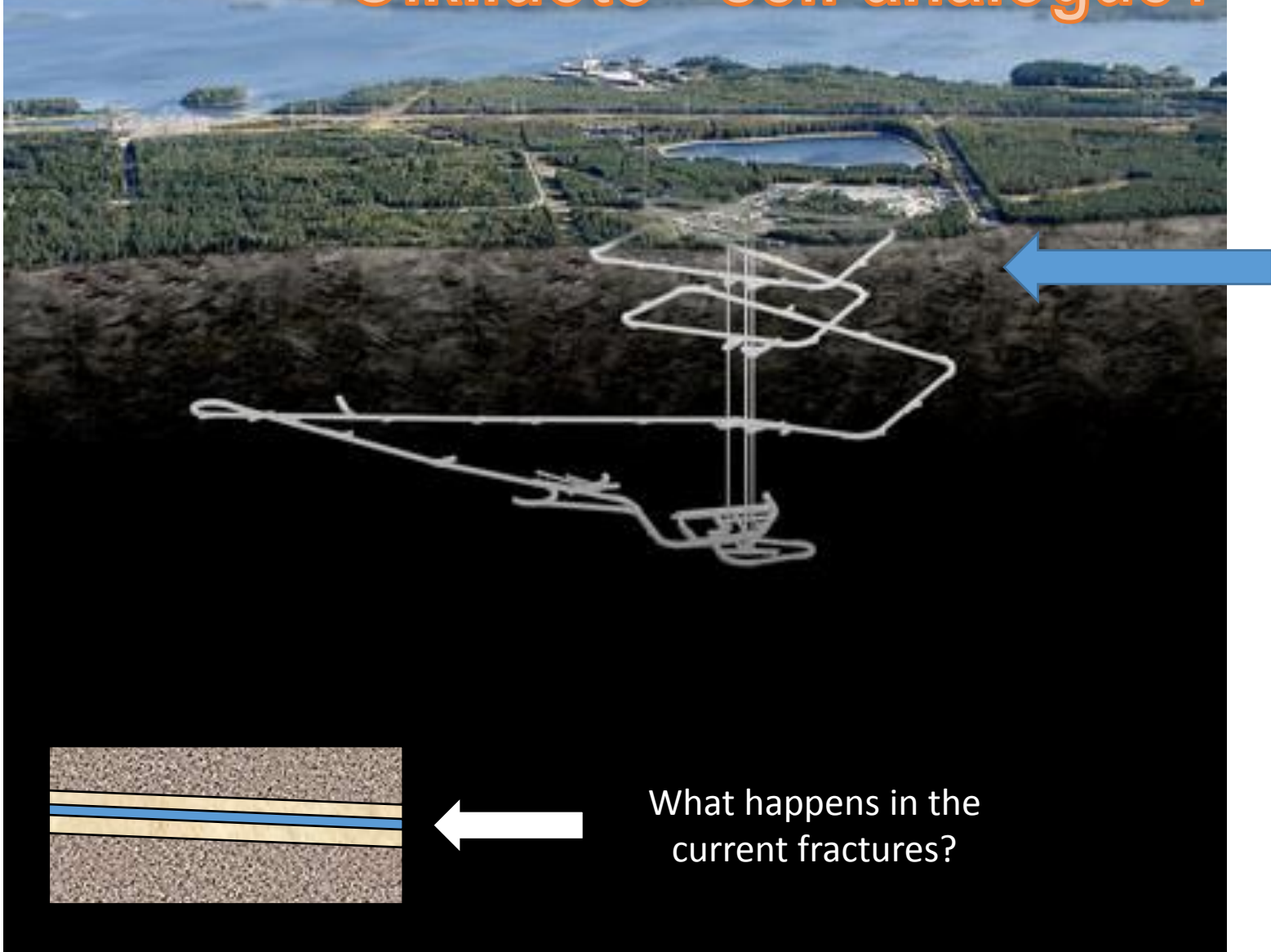


III-Natural analogues for erosion of bentonite— Arriving Olkiluoto?





Olkiluoto - self analogue?



– preliminary studies ongoing on fracture smectites (see Reijonen & Alexander 2015 for overall idea)

		Fraction		
		<2 μm	2-20 μm	20-63 μm
Sample PL70	Montmorillonite	x		x
Sample PL81	Montmorillonite	x	x	
Sample PL87	Montmorillonite	x	x	x
Sample PL295	Montmorillonite		x	
Sample PL957	Montmorillonite	x		
Sample PL960	Montmorillonite	x	x	

Montmorillonite occurrences from ONKALO (Gehör 2007)



"Self-analogues" elsewhere?

- Smectites are observed at least in:
 - Other site selection sites in FINLAND:
 - Hästholmen (Gehör et al. 1997a, Front et al. 1999)
 - **Kivetty**, where dilute conditions exist (Gehör et al. 1997b)
 - **Romuvaara**, also dilute conditions (Kärki et al. 1997)
 - SWEDEN
 - Oskarshamn and Forsmark sites (Drake et al. 2006 and Sandström et al. 2008)
 - CANADA
 - Bruce site, (Koroleva et al. 2009)
- Smectite occurrences are wide spread → crystalline and sedimentary environments



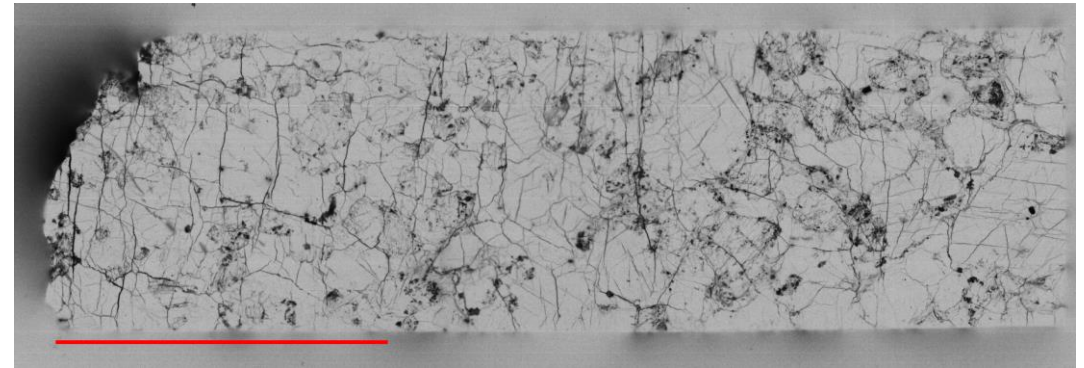
The challenge



- **Smectite occurrences are wide spread regardless of dilute conditions – why?**
- Roughness of natural fractures? – Alone?
- Other fracture surface properties? – What?
 - Mineralogical properties? – What?
- Groundwater chemistry? – nature vs. lab?
- Idea - Link between lab studies (Mayordomo et al./Madrid – destabilization of bentonite colloids by addition of alumina nanoparticles) and observations from natural samples.

Alumina hydroxide does occur in natural fractures

- Immobilization of mont./smectite colloids through sorption and precipitation processes
- Na^+ forms an outersphere complex at a distance of a few angstroms from gibbsite surface (Cygan et al. 2004)
- Nanostructure of colloidal phase and adsorbing rock surface?



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Questions:

- Have we forgotten the adsorption phenomena at the mineral-water interface?
 - For example the works of Sverjensky (2005) and others (e.g. Stumm 1992; Hiemstra et al. 1987, Papirer 2000) on surface chemistry?
- Any idea on what would be the flow velocity (hydraulic conductivity) threshold that limit/hampers adsorption?



Conclusions

- FACTS
 - Dilute conditions could be encountered at repository depth, though at some places (e.g. Olkiluoto) the structural geology may pose a limitation
 - Smectite/montmorillonite is found in water-conducting fractures carrying dilute waters
 - **Something limits chemical erosion in them – need to understand**
- Still – we need to consider chemical erosion in the safety case, but a better understanding would avoid making too conservative assumptions in the estimation of the consequences.



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