

Numerical modelling of steel waste package corrosion and mechanical strength

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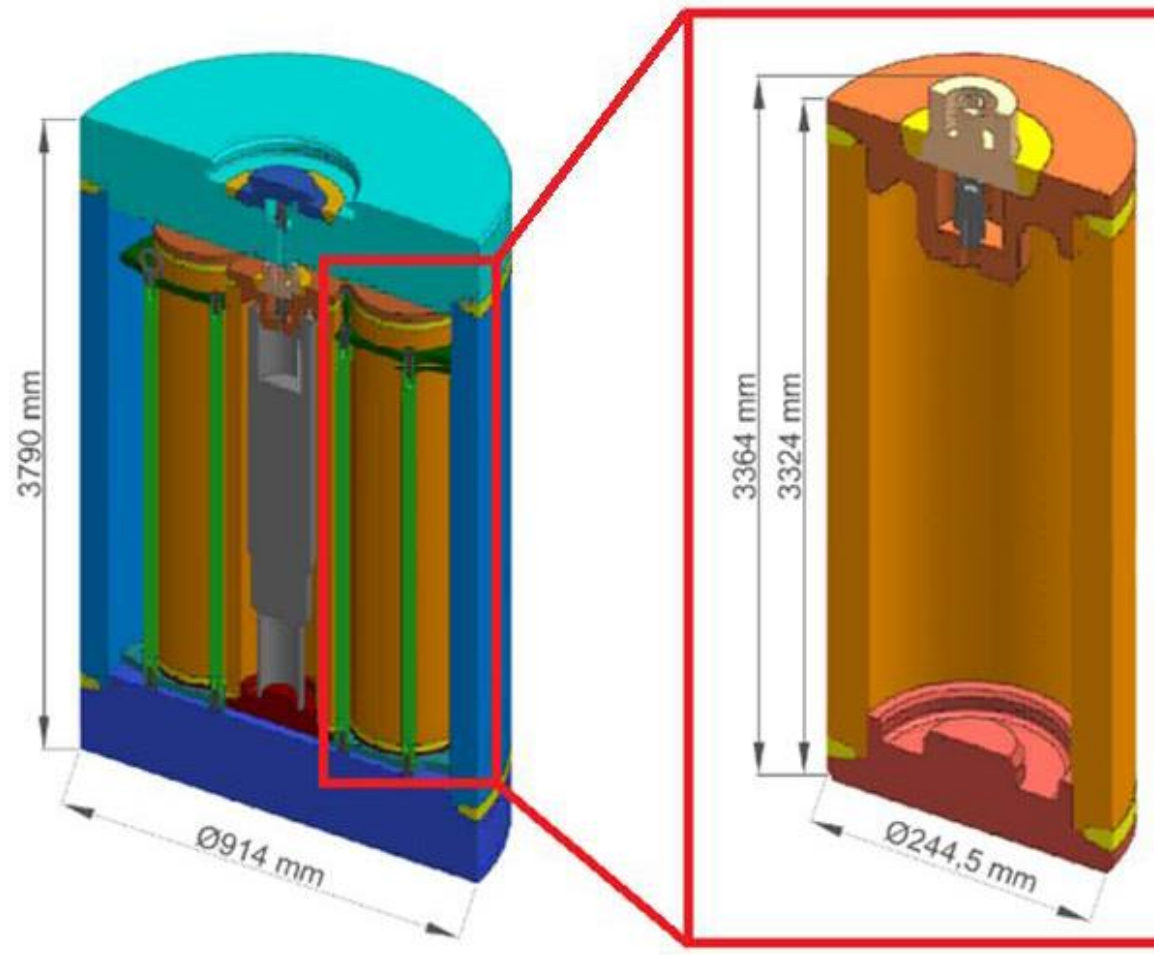
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Introduction

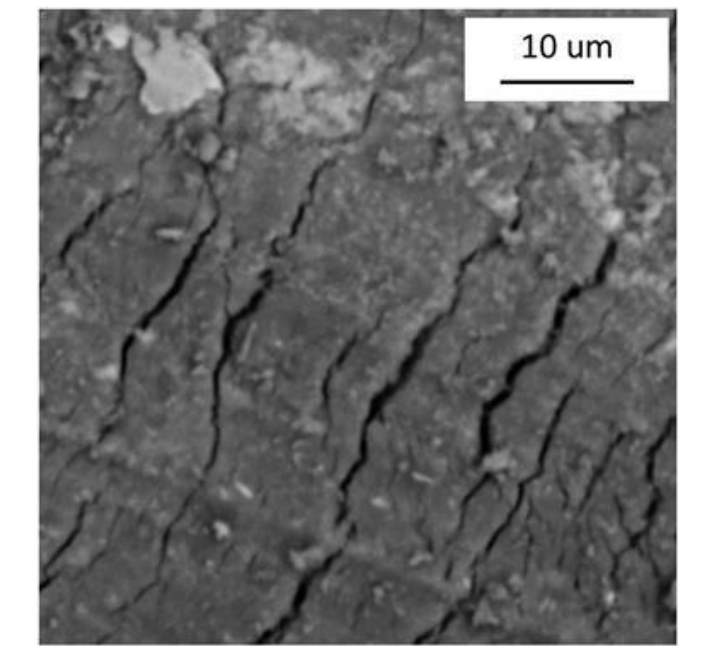
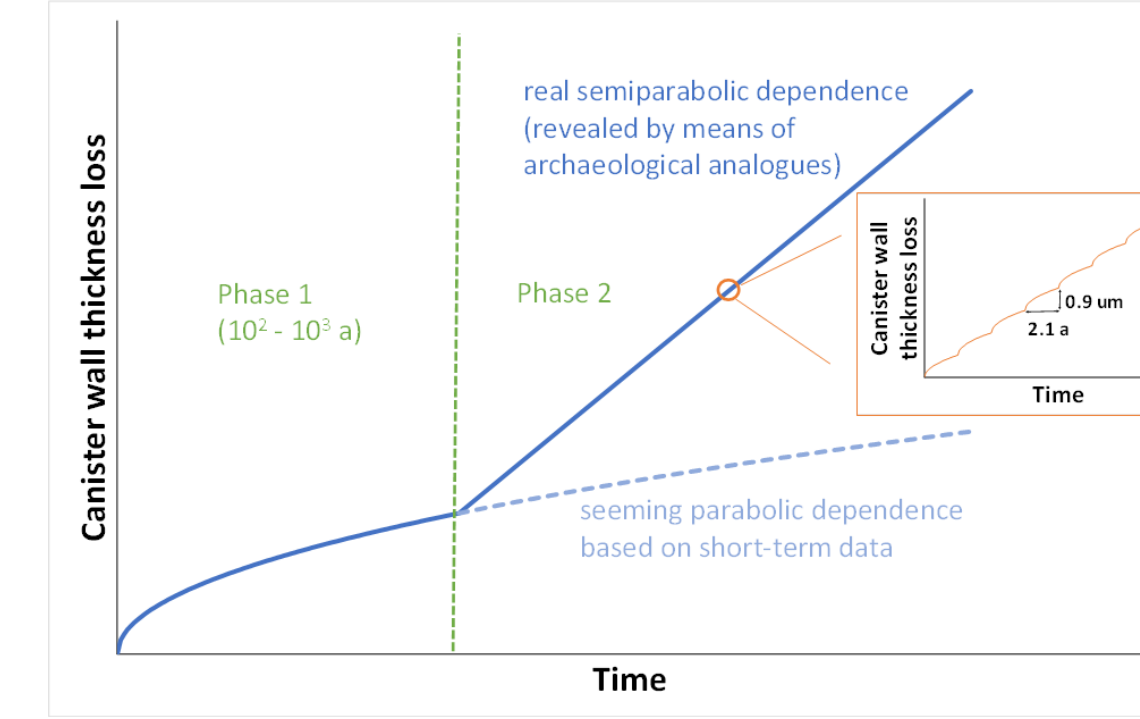
- Research for Czech spent nuclear fuel disposal program (SÚRAO).
- Specific concept of disposal package (canister) and local bentonite sources.
- Support for the canister lifetime proof in the future safety case
- Continuation of previous experimental and modelling studies on steel corrosion in bentonite (Gondolli et al., 2018).
- Results: Šembera et al. 2025, SÚRAO report TZ837/2025/Eng

SÚRAO's double-case waste disposal package



- Design by Škoda JS (Forman et al., 2021)
- Outer case of carbon steel: predictable uniform corrosion during limited time ... this study
- Inner case of stainless steel: provides the final lifetime, with a passive corrosion regime under favourable conditions (temperature, pH, ...) after the outer case lifetime period

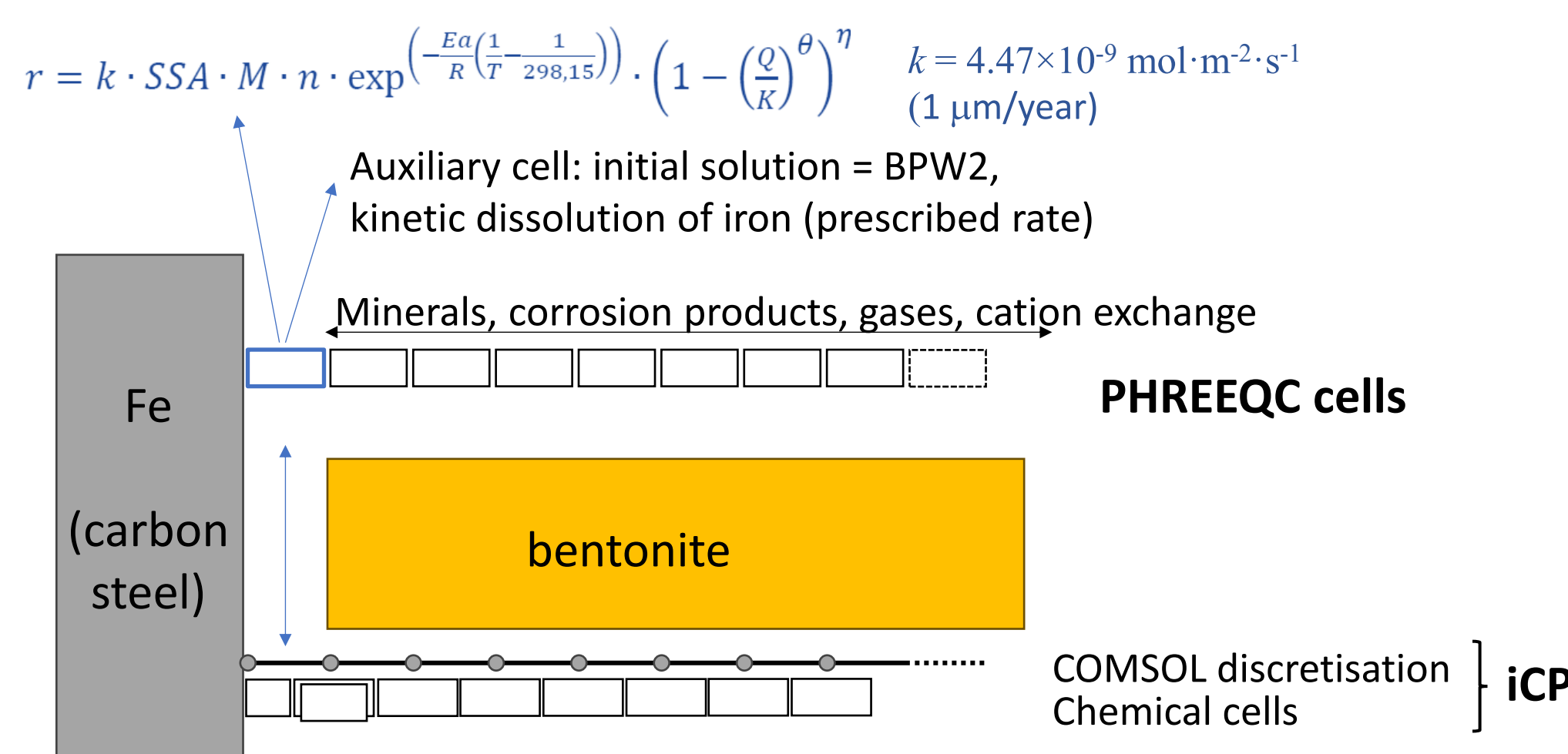
Supporting experimental data



- Laboratory corrosion tests: (Forman et al. 2021, Gondolli et al. 2018, Smart et al 2024)
- Archaeological analogues: corrosion products on excavated artefacts)
- Rates of 0.1-20 µm/year
- Anoxic corrosion products: magnetite, chukanovite, siderite

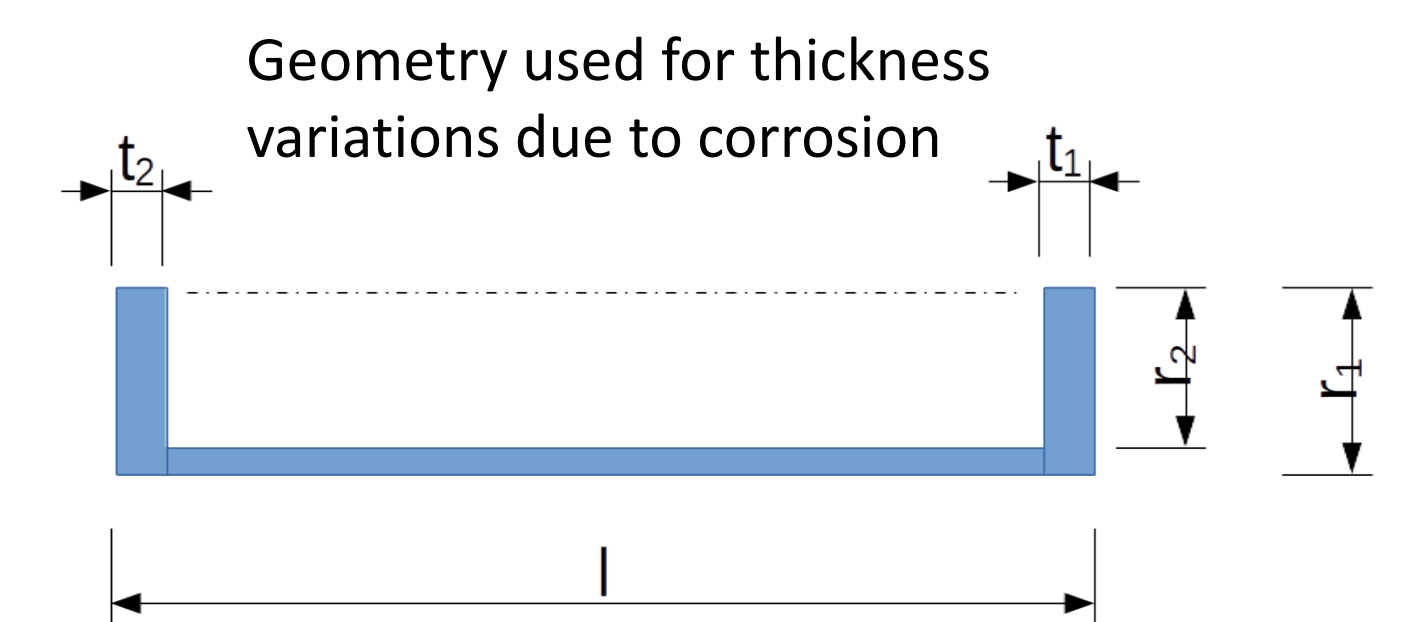
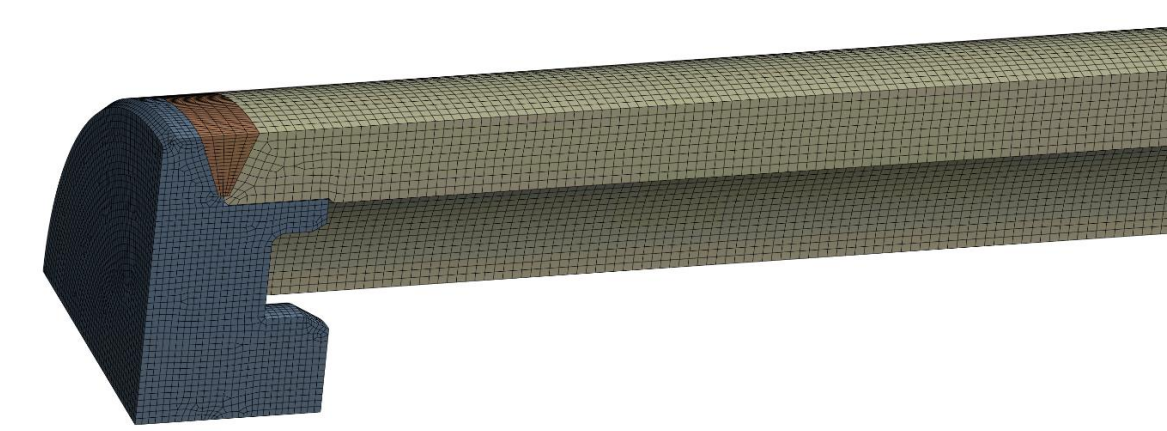
Reaction-transport modelling

- Corrosion products change the bentonite transport properties... prescribed corrosion rate is reduced
- Reactive transport in bentonite includes: multi-porosity concept (free bulk water for reactions and transport), ion-exchange and surface sites, atmospheric gases, kinetic precipitation/dissolution.
- Software: PHREEQC and iCP (PHREEQC+COMSOL Multiphysics)
- Thermochimie database
- Czech bentonite from local deposits ... Ca-Mg type, reference material BCV ... "bentonit Černý vrch" = deposit name
- Pore water composition measured and modelled (prior work) ... BPW

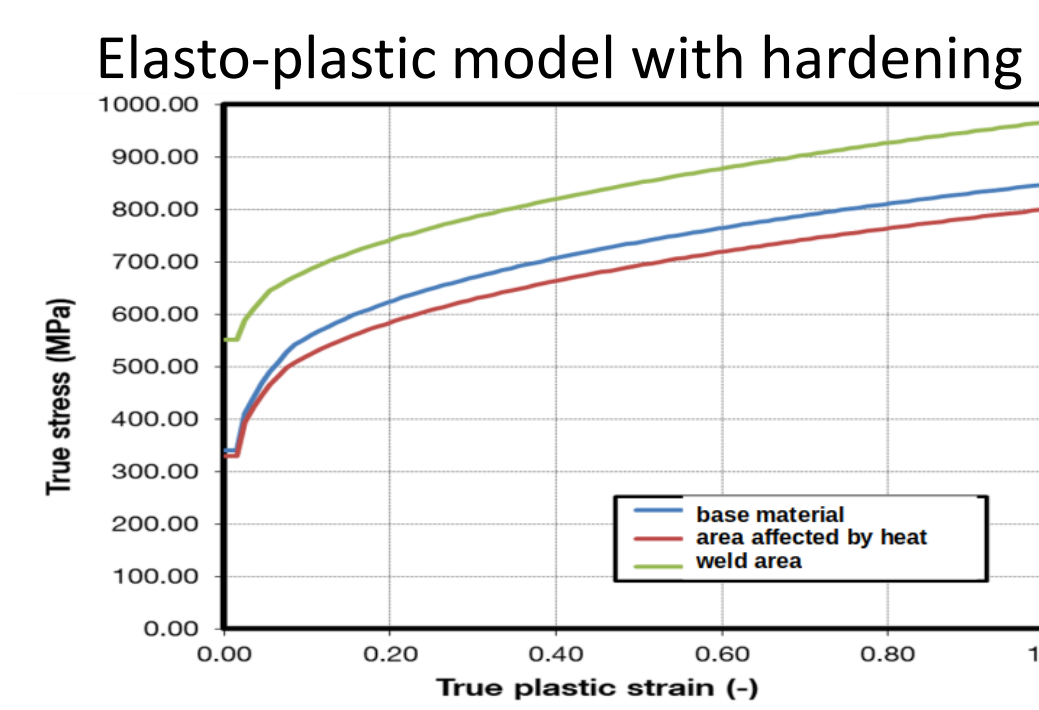


Mechanical strength modelling

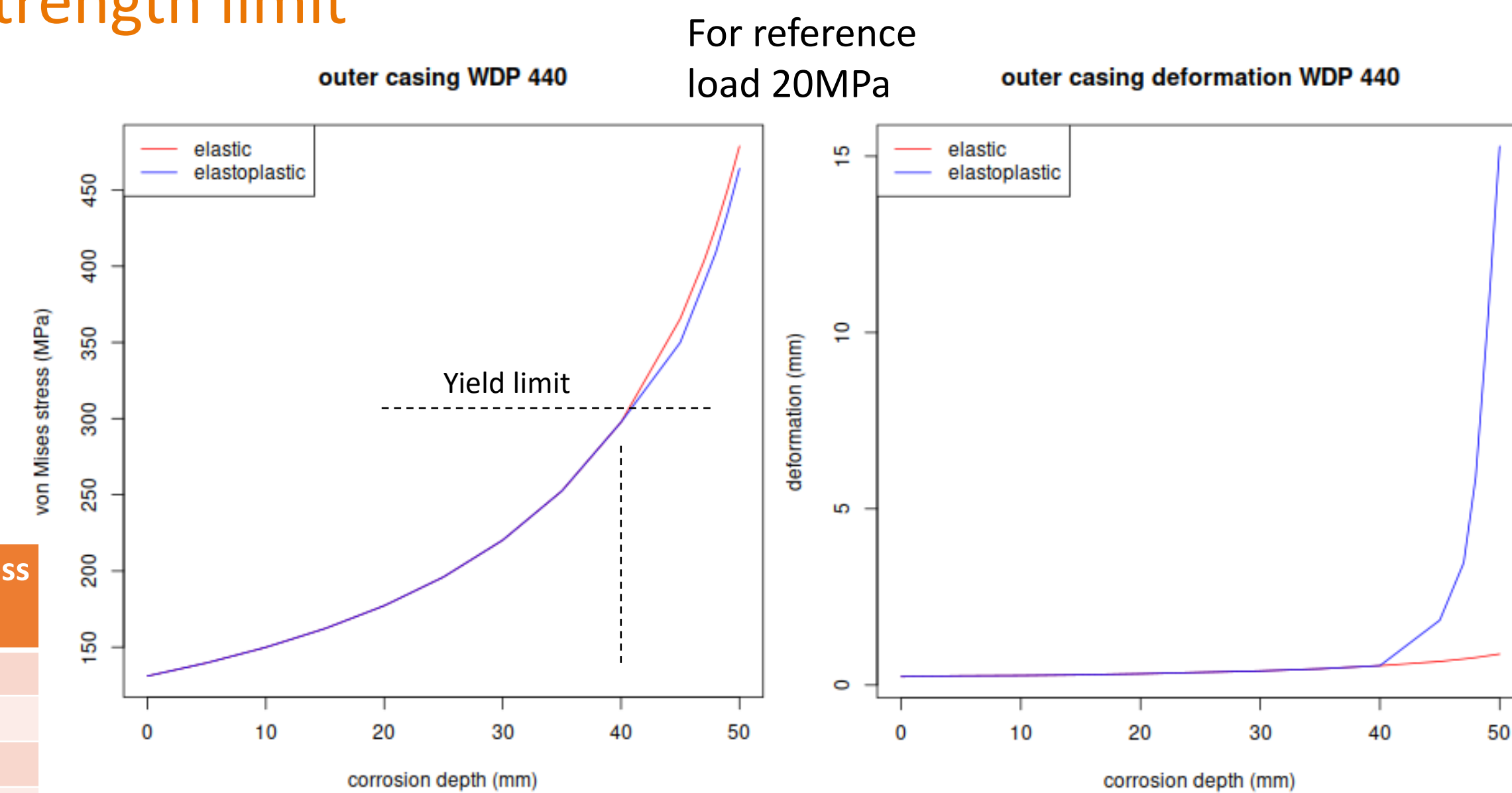
Reference finite element model (verification)



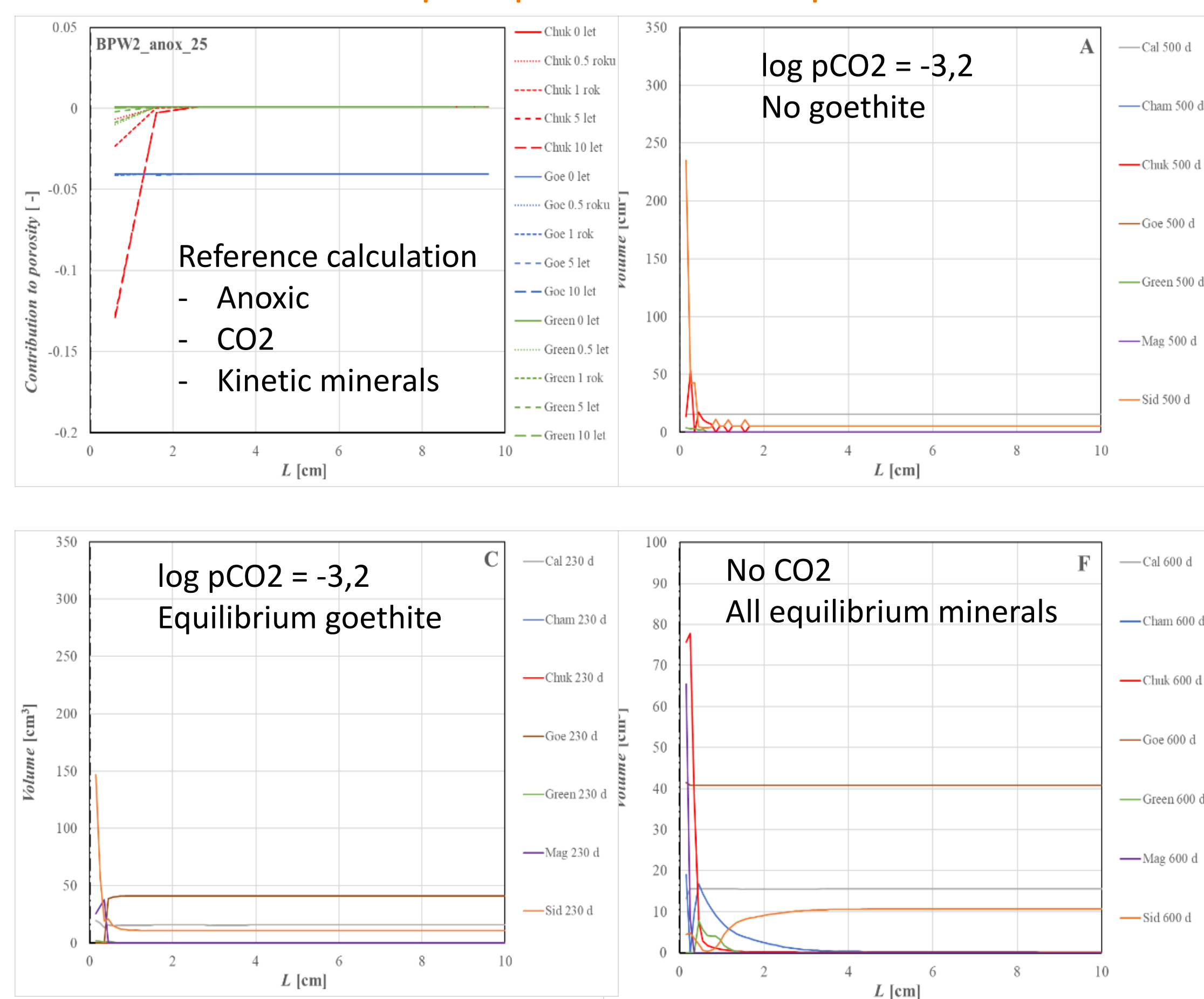
Static calculation – strength limit



	corrosion depth (mm)	casing thickness (mm)
Outer casing WDP 1000	49	16
Outer casing WDP 440	49	16
Inner casing WDP 1000	34.5	5.5
Inner casing WDP 440	31.5	3.5

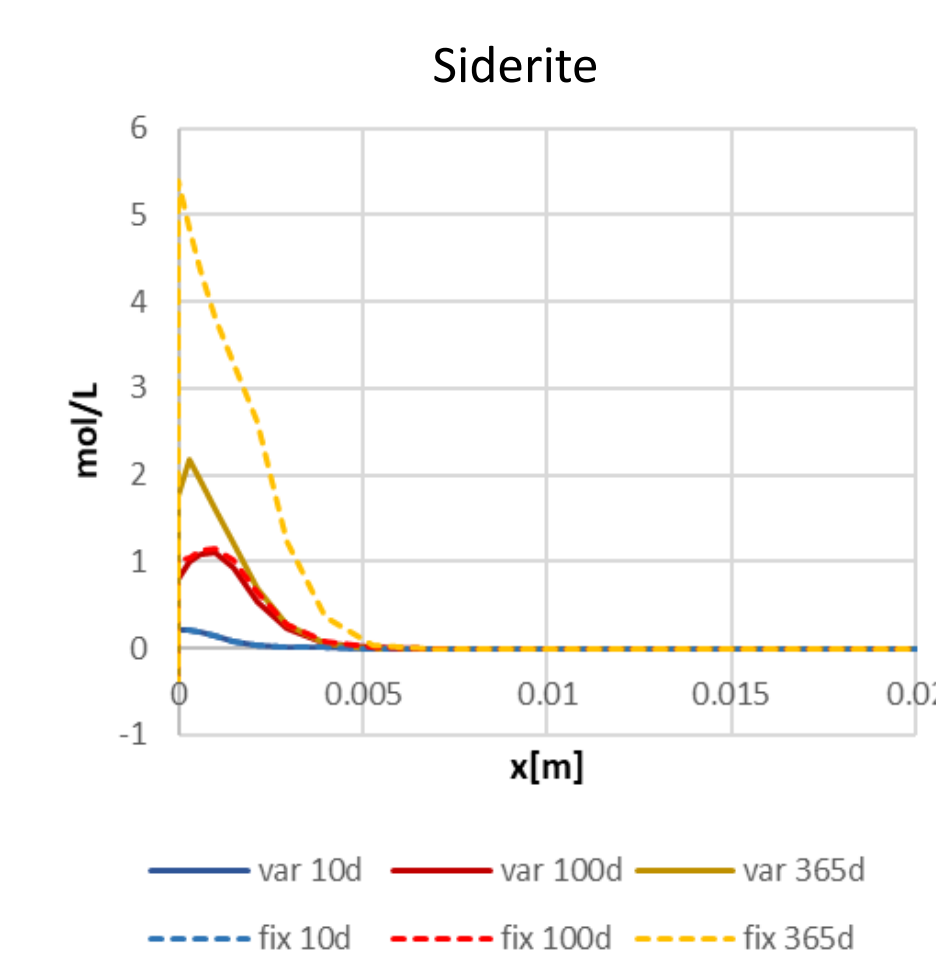
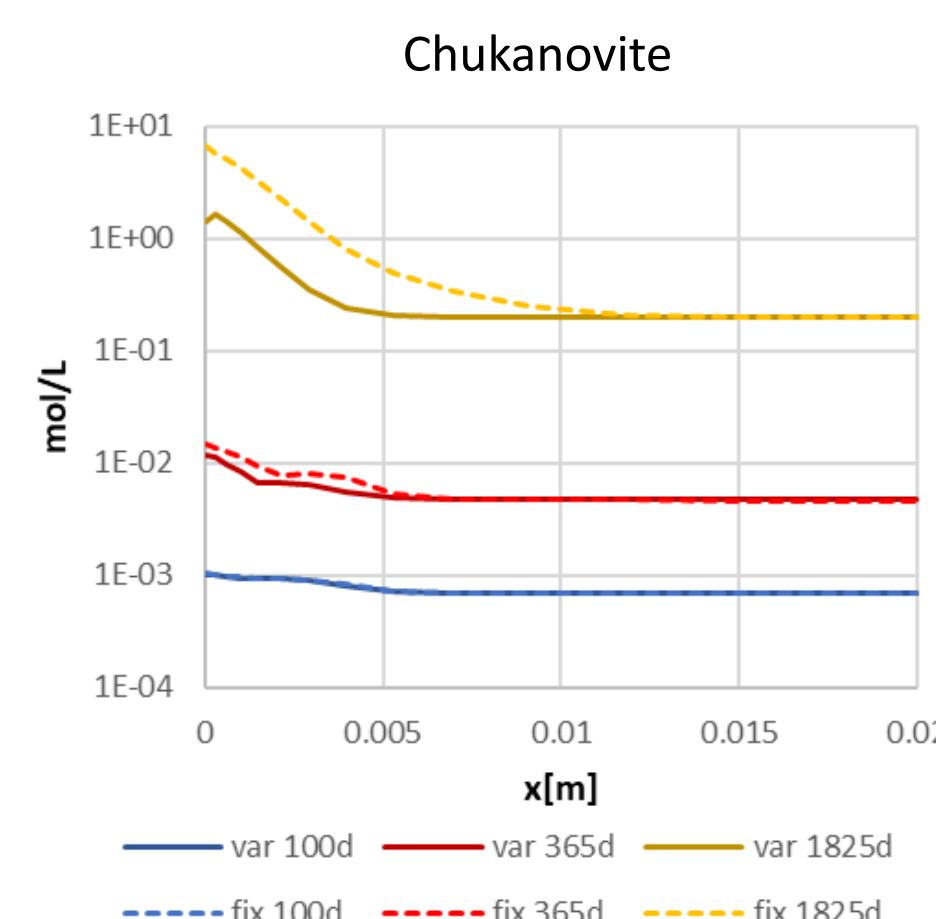


Results – precipitated mineral profiles

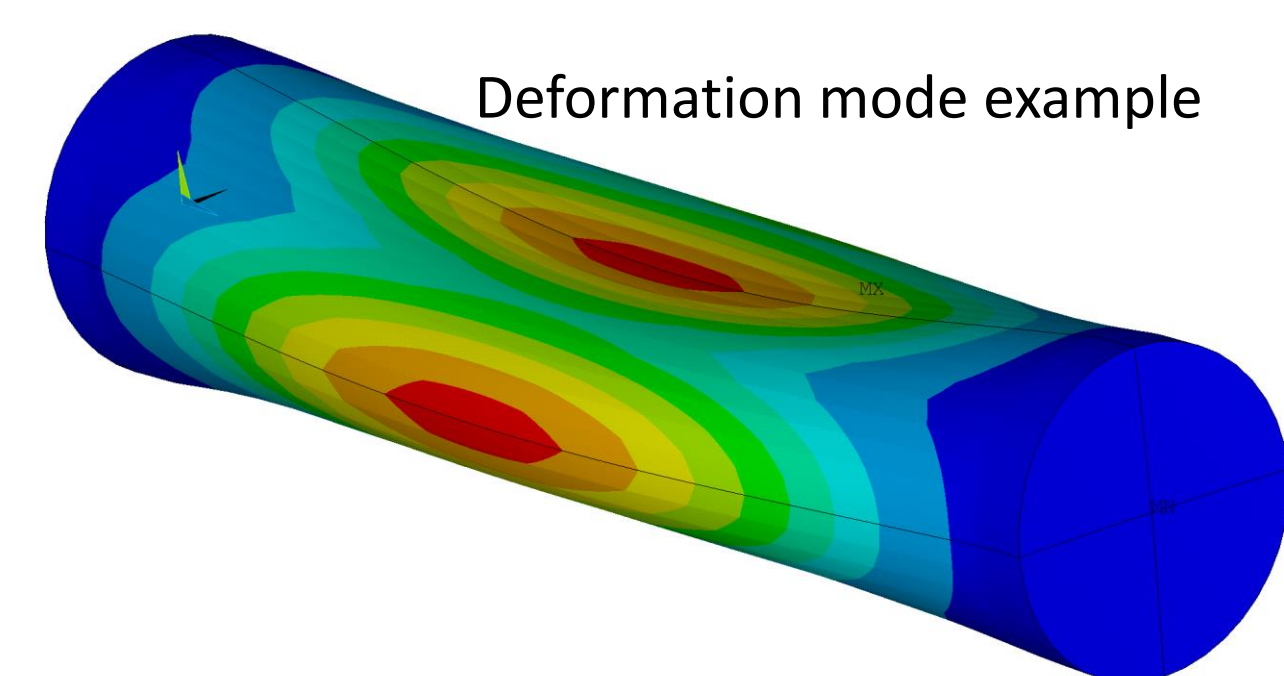


Effect of porosity change

- Variable (coupled model)
- Fixed (uncoupled)
- 1 year / 5 years

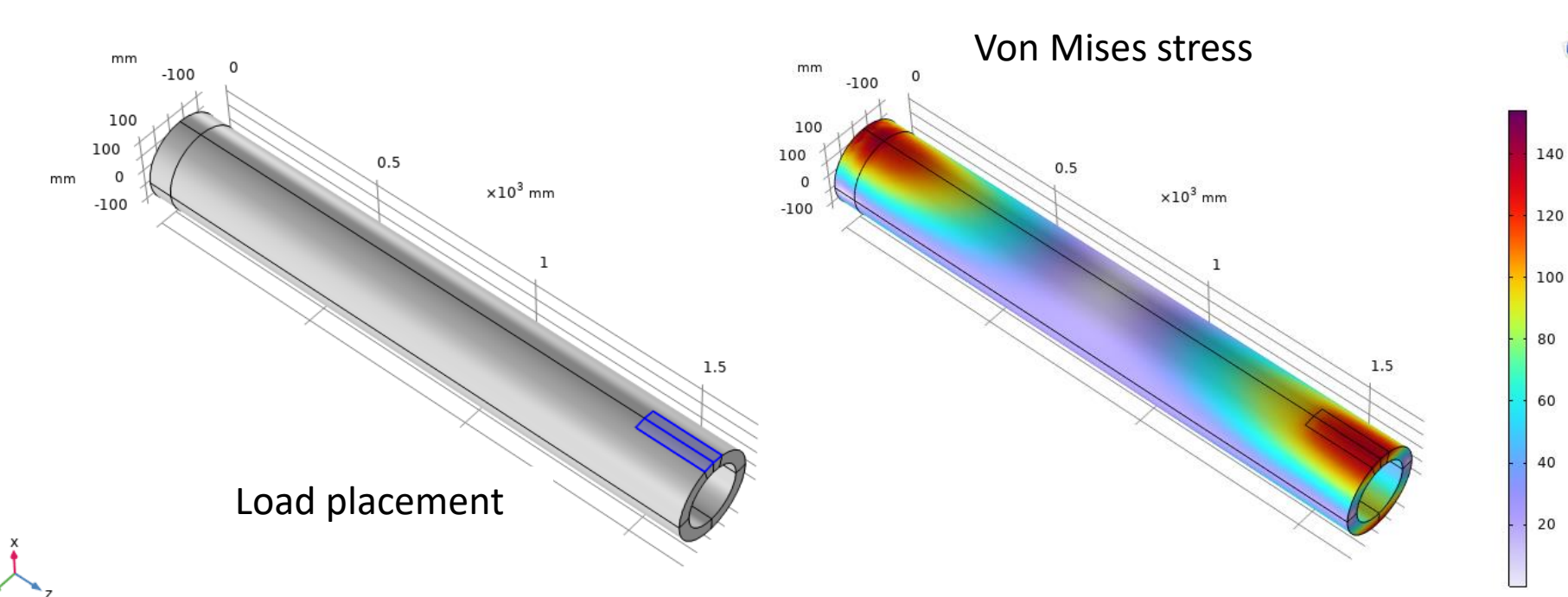
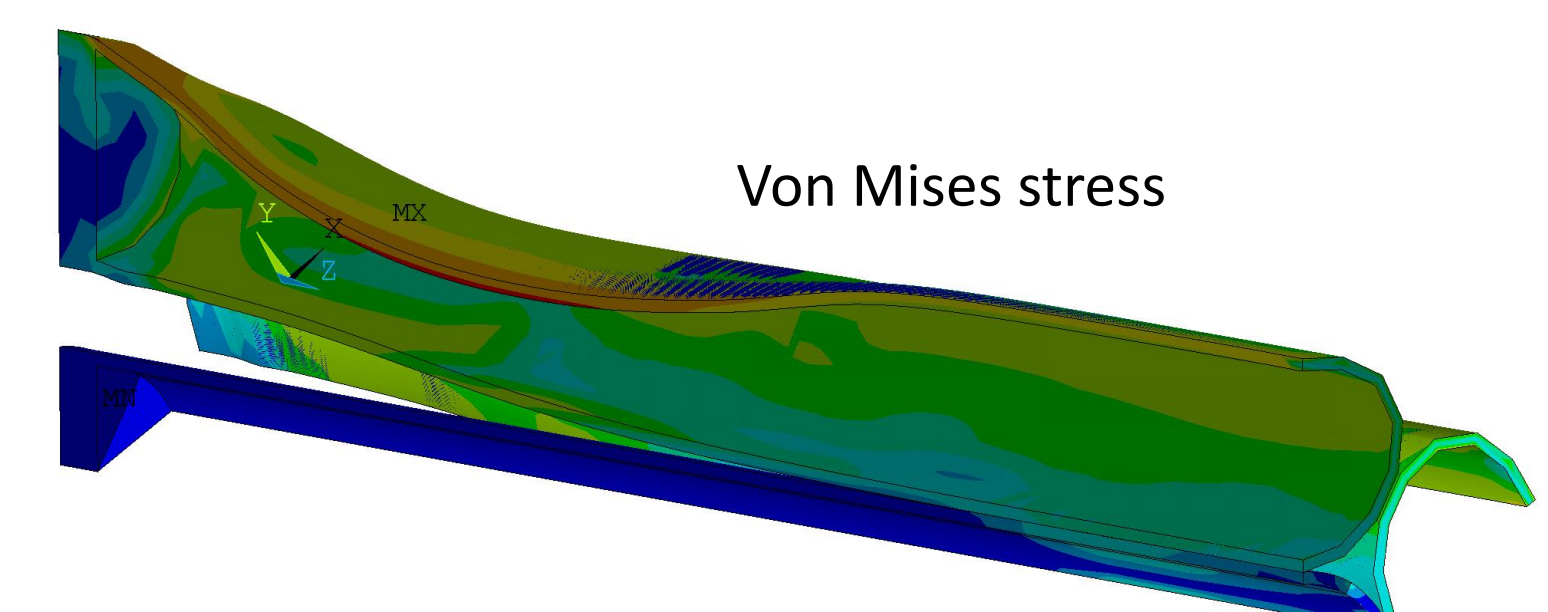
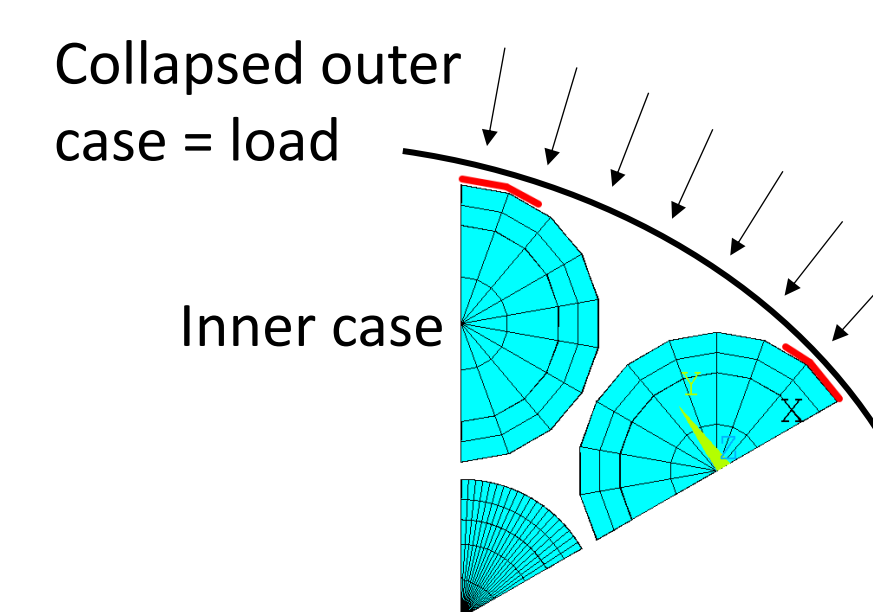


Buckling calculation – shape stability limit



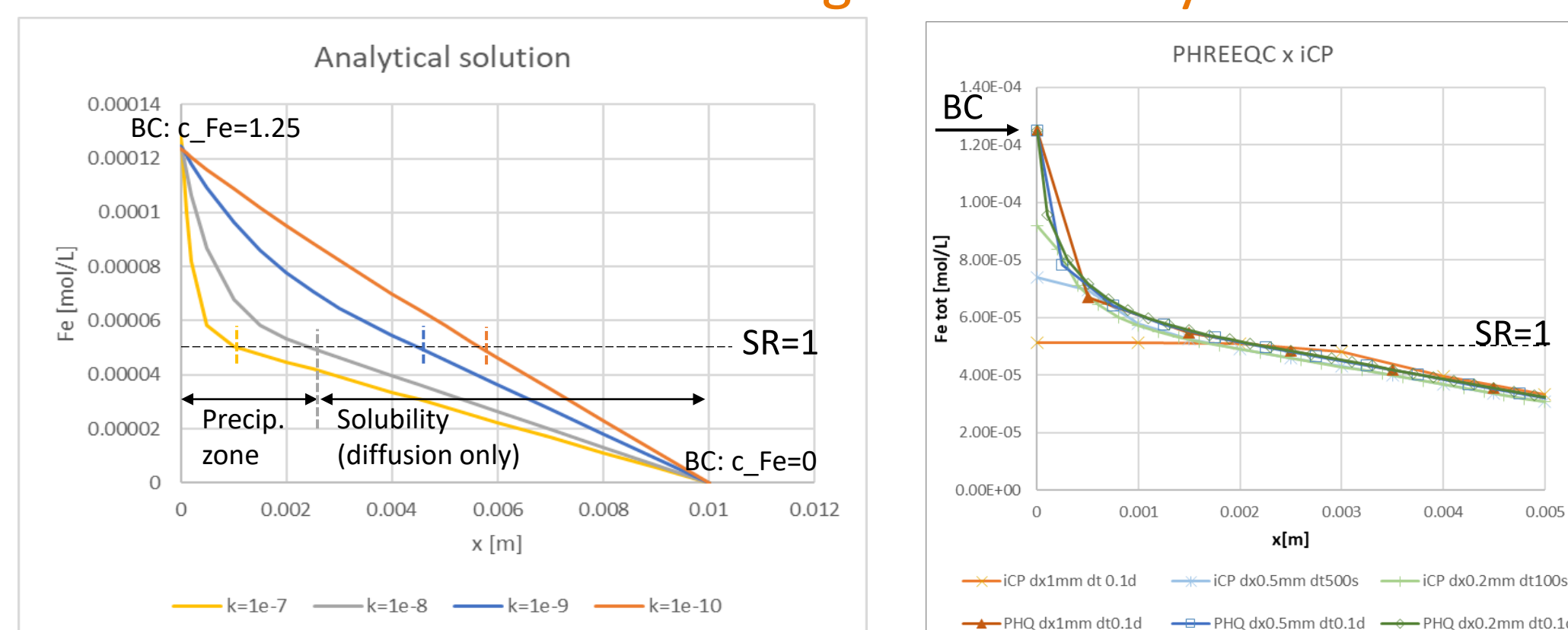
Resulting limits		
corrosion depth (mm)	critical load (MPa)	
15	85.62	
20	67.13	
25	51.15	
30	38.15	
35	27.19	Reference Load 20MPa
40	17.84	
45	10.35	
50	5.68	

Calculation of inner case load – contact problem



- Shape stability is the limiting collapse mode
- Enough strength for uniform reference load (swelling pressure + hydrostatic + uncertainty)
- Contact forces can produce less favourable loads on the inner case

Discretisation effects – convergence to analytical solution

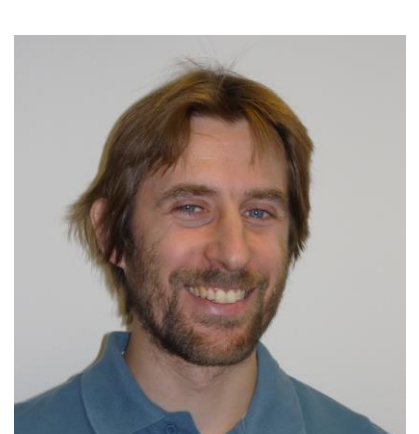


References

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Acknowledgement

The work was performed as part of the Radioactive Waste Repository Authority (SÚRAO, Czechia) project, "Research support for the safety assessment of a deep geological repository", contract SO2021-053.



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25th November 2025 to 27th November 2025