Coupled Palaehydrogeological Microbial and Geochemical Reactive Transport Model of the Olkiluoto Site (Finland)

P. Trinchero[1], M. Luna[1], J. Molinero[1], G. Román-Ross[1], F. Maia[1], A. Nardi[1], J. Löfman[2], Petteri Pitkänen[3], L. Koskinen[3]

[1]Amphos 21 Consulting, [2]VTT Energy, [3]Posiva Oy

Introduction

Olkiluoto at Eurajoki has been selected as the final repository site for spent nuclear waste in Finland. This area has been affected, at regional scale, by land-uplift processes related to the ice withdrawal These events have resulted in a complex and stratified heterogeneous hydrochemical system.
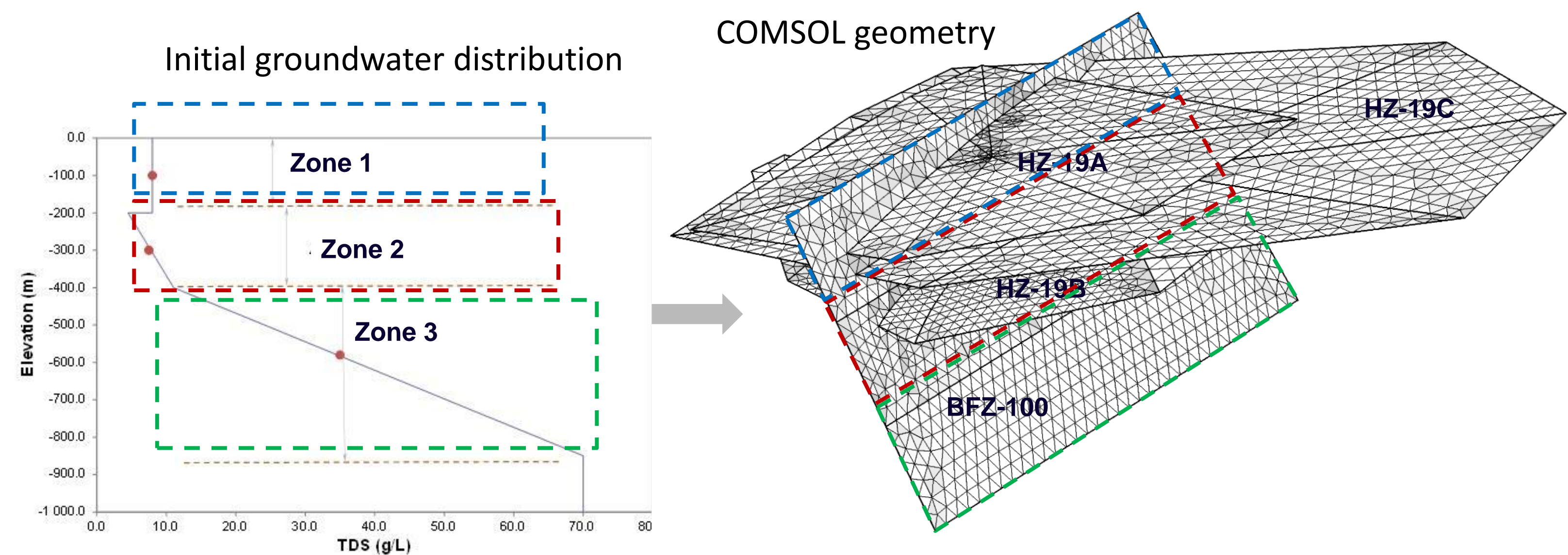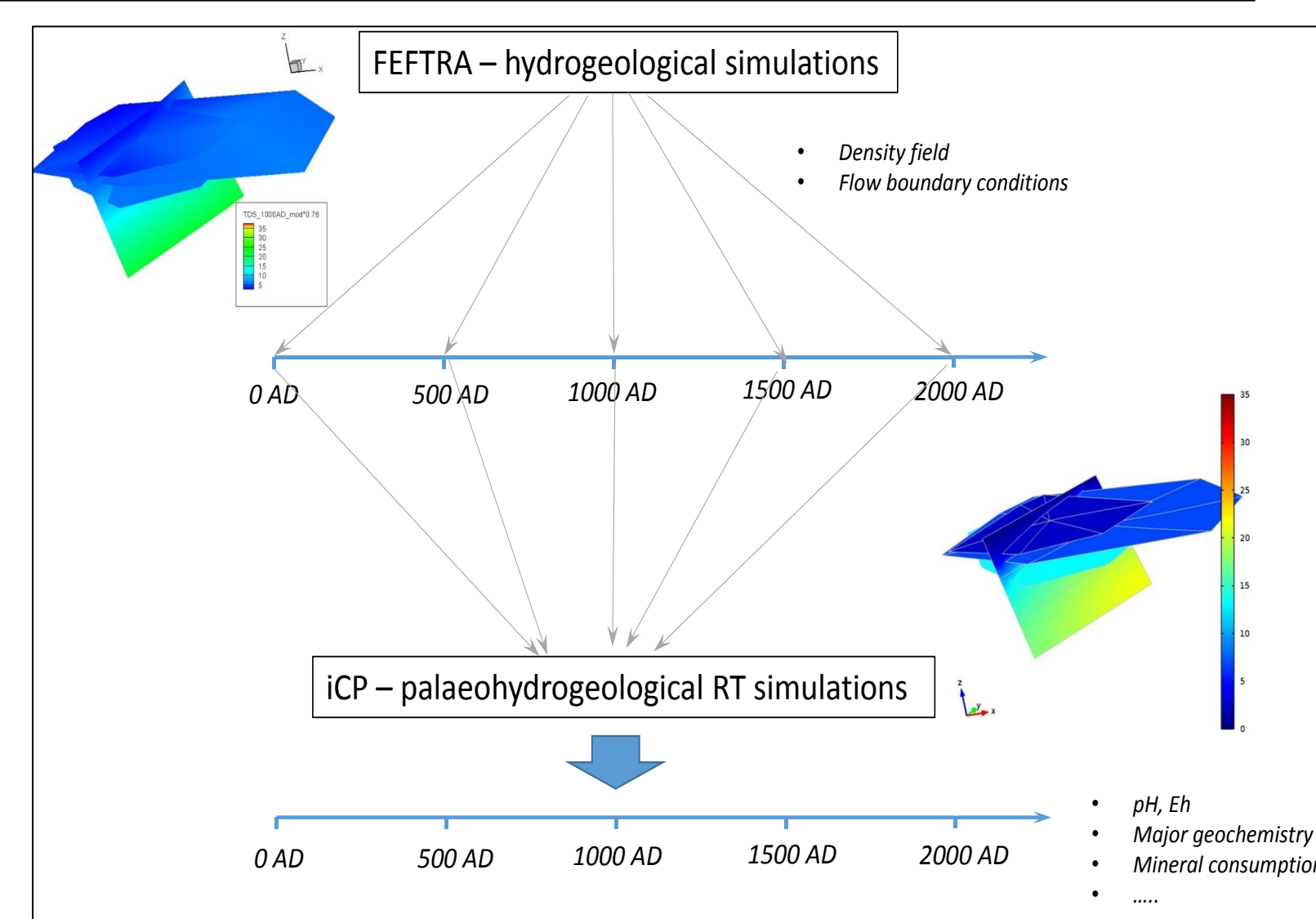
The objective of this work was to develop a robust paleohydrogeological reactive transport (PRT) model that, through a better understanding of the implications of the past events, might help to improve the knowledge of the present-day hydrogeochemical condition conditions at Olkiluoto, thus allowing to increase the reliability of future predictions.
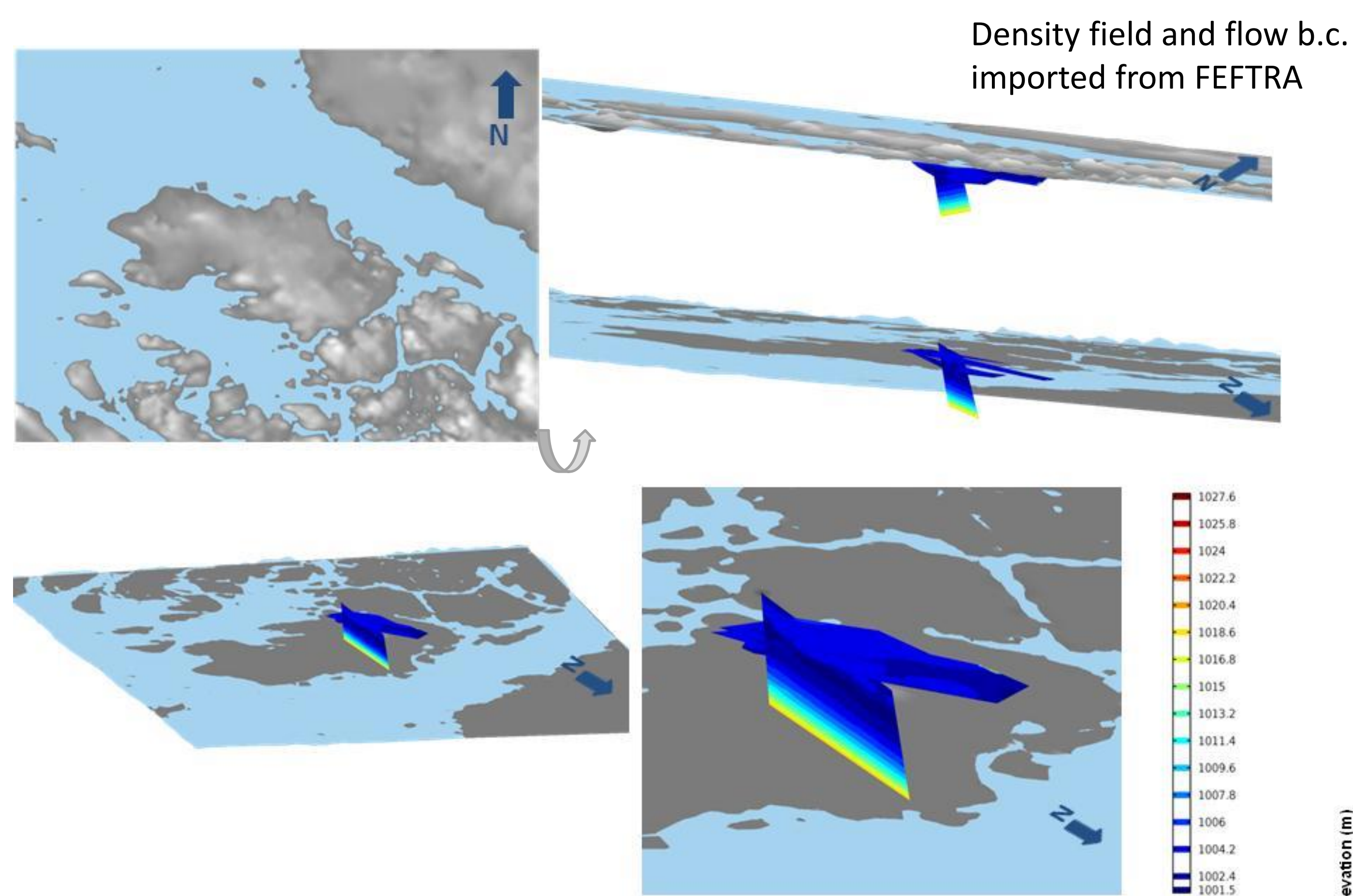
Numerical model

- Hydrogeological conditions based on the geometrical configuration and results of existing regional-scale hydrogeological models (i.e. FEFTRA models, Löfman & Karvonen, 2012).
- The model considers three types of initial waters, which define three different hydrochemical zones.
- The domain consist of four Hydrogeological Zones (HZs).
- Reactive transport simulations aim at studying the potential for sulphide generation and key buffering reactions that may control sulphate reduction.
- The paleohydrogeological reactive transport simulations have been carried out using the interface Comsol-Phreeqc (Nardi et al., 2012).
- Dual porosity processes have been included to mimic exchange of mass between the mobile zones and the matrix.

Model features

Density field and flow b.c. imported from FEFTRA

Initial groundwater distribution

COMSOL geometry

Chemical processes considered

(1) calcite and pyrite/FeS(am) dissolution/precipitation;
(2) aluminosilicates weathering; (3) cation exchange reactions;
(4) aqueous redox reactions

Mineral	Reaction	Log K
FeS$_{(am)}$	$FeS + H^+ = Fe^{2+} + HS^-$	-2.95
Calcite	$CaCO_3 = CO_3^{2-} + Ca^{2+}$	-8.48
Albite	$NaAlSi_3O_8 + 8 H_2O = Na^+ + Al(OH)_4^- + 3 H_4SiO_4$	-18.002
illite	$K_{0.6}Mg_{0.25}Al_{2.3}Si_{3.5}O10(OH)_2 + 11.2H_2O = 0.6K^+ + 0.25Mg^{2+} + 2.3Al(OH)_4^- + 3.5 H_4SiO_4 + 1.2H^+$	40.267
K-feldspar	$KAlSi_3O_8 + 8 H_2O = K^+ + Al(OH)_4^- + 3 H_4SiO_4$	-20.573
Siderite	$FeCO_3 = Fe^{2+} + CO_3^{2-}$	-10.89
SiO$_{2(am)}$	$SiO_2 + 2 H_2O = H_4SiO_4$	-2.71
Kaolinite	$Al_2Si_2O_5(OH)_4 + 6 H^+ = H_2O + 2 H_4SiO_4 + 2 Al^{3+}$	7.435

Results

Sulfide at 2000 AD

Conclusions

- A complex reactive transport model has been successfully implemented and solved.
- The model complexity comes from the geometrical configuration of the domain (i.e. a set of intersecting planes in a 3D domain), the need to couple the flow conditions to the FEFTRA's results and the intrinsic complexity of geochemical reactions.
- The reactive transport model accounts for the exchange of mass between the mobile domain (fractures) and the surrounding matrix blocks.
- The model results, which fit well with measured data at Olkiluoto, help to infer key information about the buffering capacity of the medium.

References

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