Characterisation of Matrix Porewater in Carbonate Sedimentary Rocks (Bulach, Switzerland)

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Background and Study Site

The Bulach borehole in the Zurich Nordost is under investigation for the building of a deep geological repository for the disposal of radioactive waste from nuclear power plants. The study of porewater-groundwater interaction gives insights about the evolution of the bedrock fluids for the safe disposal of radioactive waste to protect groundwater resources.

Figure 1: Well site plot of Borehole Bülach 1

Aim:
- To discover the paleohydrological history of the site by comparing non-reactive, conservative elements Cl^- and Br^- contents of the two water reservoirs as well as their stable water isotopic signatures; δO^{18} and δH^2.
- Testing of out-diffusion experiment on sedimentary rocks

Concept:
Chemical Gradients are established between groundwater and porewater as they slowly equilibrate over time. Matrix porewater is a dynamic water reservoir residing in connected pores of low permeability rocks, it interacts with its surroundings by diffusion transport.

To understand the extent of this interaction, characterizing its composition is critical to know the residence time of the fracture groundwater nearby. The matrix porewater may preserve the composition of past groundwaters for long geological periods.

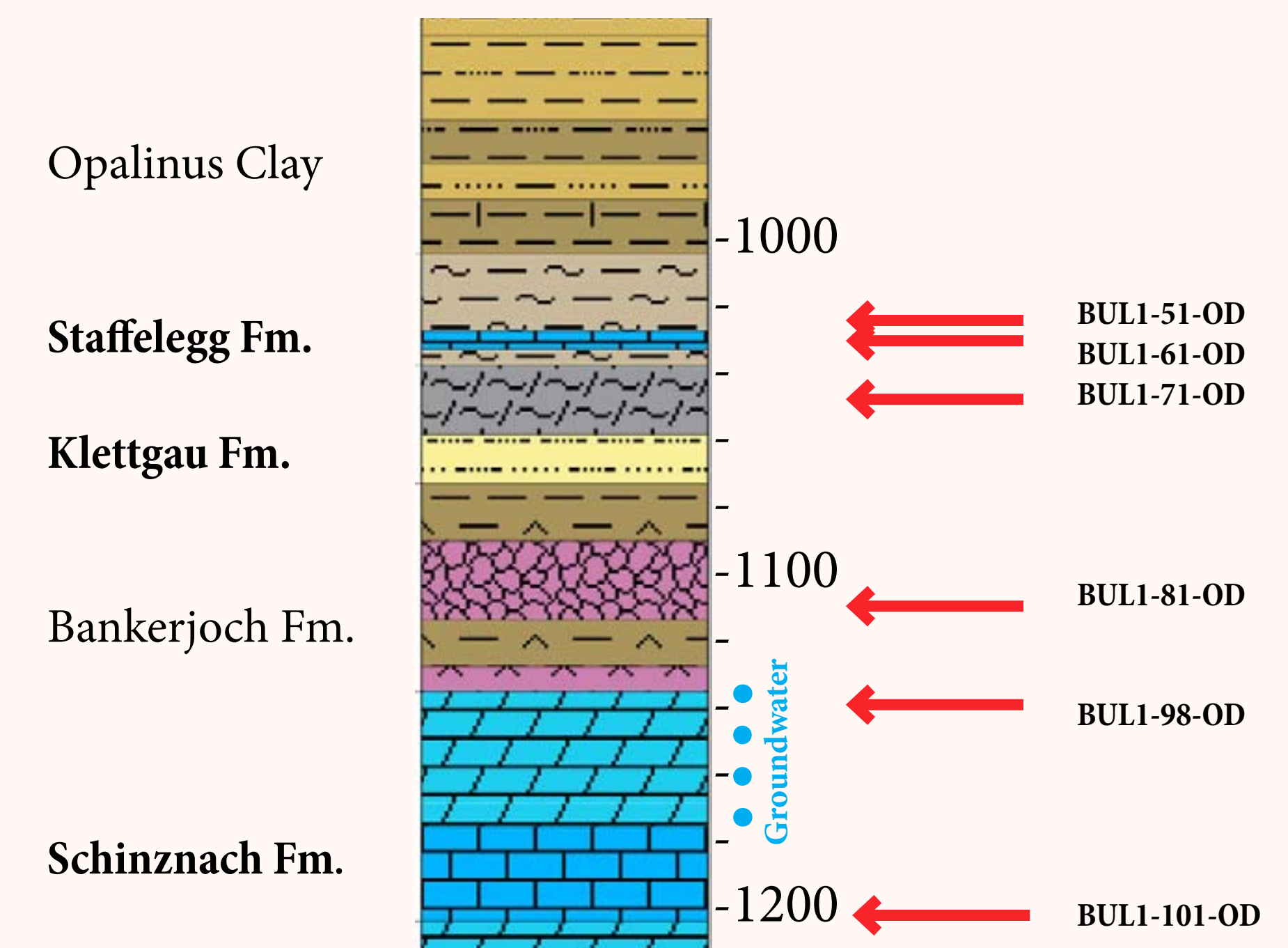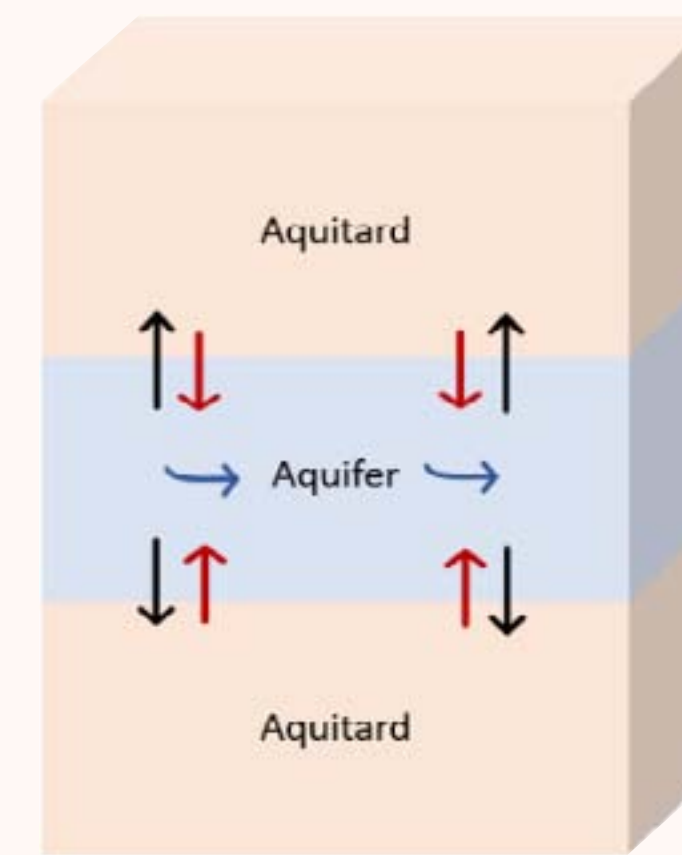Figure 3: Chemical gradient concept between low and high permeability rocks.

Figure 2: Lithostratigraphic section of BUL1-1B showing the 6 drill core samples

Six drill core samples from formation Staffelegg, Kletgau and Schinznach are investigated below the proposed host rock Opalinus Clay.

Laboratory Experiments and Methods

Porewater can only be extracted by indirect methods performed on originally saturated rocks
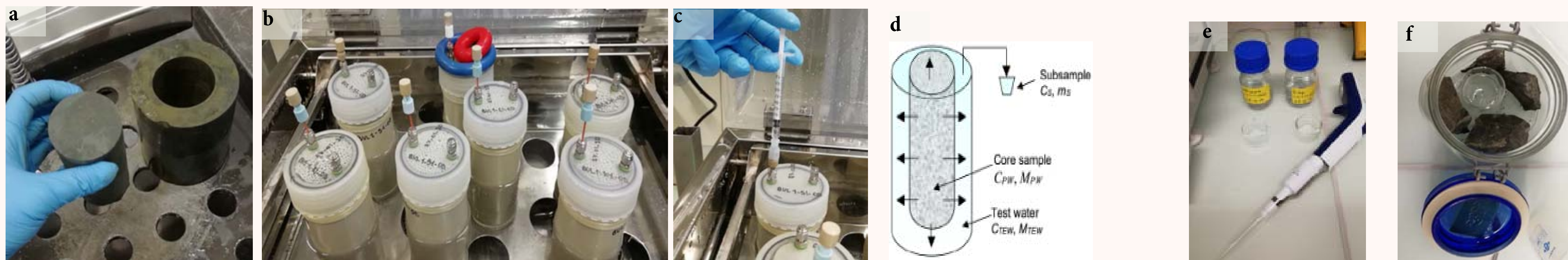

Figure 4:
a) Saturated Core for Out-diffusion versus Unsaturated Rim for Petrophysical investigations.
b) Out-diffusion water bath and vessels.
c) Extraction procedure of 0.5mL subsamples.
d) out-diffusion concept showing concentration and mass of test water, porewater and subsample.
e) Two different origins of test waters
f) Isotope exchange container with saturated rock pieces

Out-Diffusion Set-Up:

- Aqueous leaching of core cylinder in ultrapure water in a closed vessel.
- Containers placed in 45°C swaying water bath for ~250 days.
- Extraction of 0.5mL time-series samples at regular time intervals.
- Measures; pH, Titration, IC analysis of subsamples and final solutions.

Isotope Exchange: Two identical experiments
- Two test solutions of different δO^{18} and δH^2
1) LAB (normal tap water close to the expected porewater composition).
2) NGW (collected from Greenland Icecore, far from expected porewater composition).
- Saturated rock pieces in vapor-tight containers surrounding a test water.
- Stored until equilibration via the gas phase.

Preliminary Results

Rock Properties

Sample	Rock Type	WL porosity vol%	
		OD Cores	AqEx Rock Pieces
BUL1-51-OD	calcareous marl	18.55	18.47
BUL1-61-OD	clay-bearing limestone	9.19	8.30
BUL1-71-OD	argillaceous marl	11.74	11.15
BUL1-81-OD	clay-bearing anhydrite	3.27	8.19
BUL1-91-OD	dolostone	18.48	15.69
BUL1-101-OD	anhydrite-bearing dolostone	7.48	7.46

Figure 5: Rock Type was derived from XRD mineralogical analysis.
Water-Loss porosity was obtained from gravimetric drying, it gives the mass of porewater through which the derivation of the pore diffusion coefficients of Cl^- and Br^- is possible.
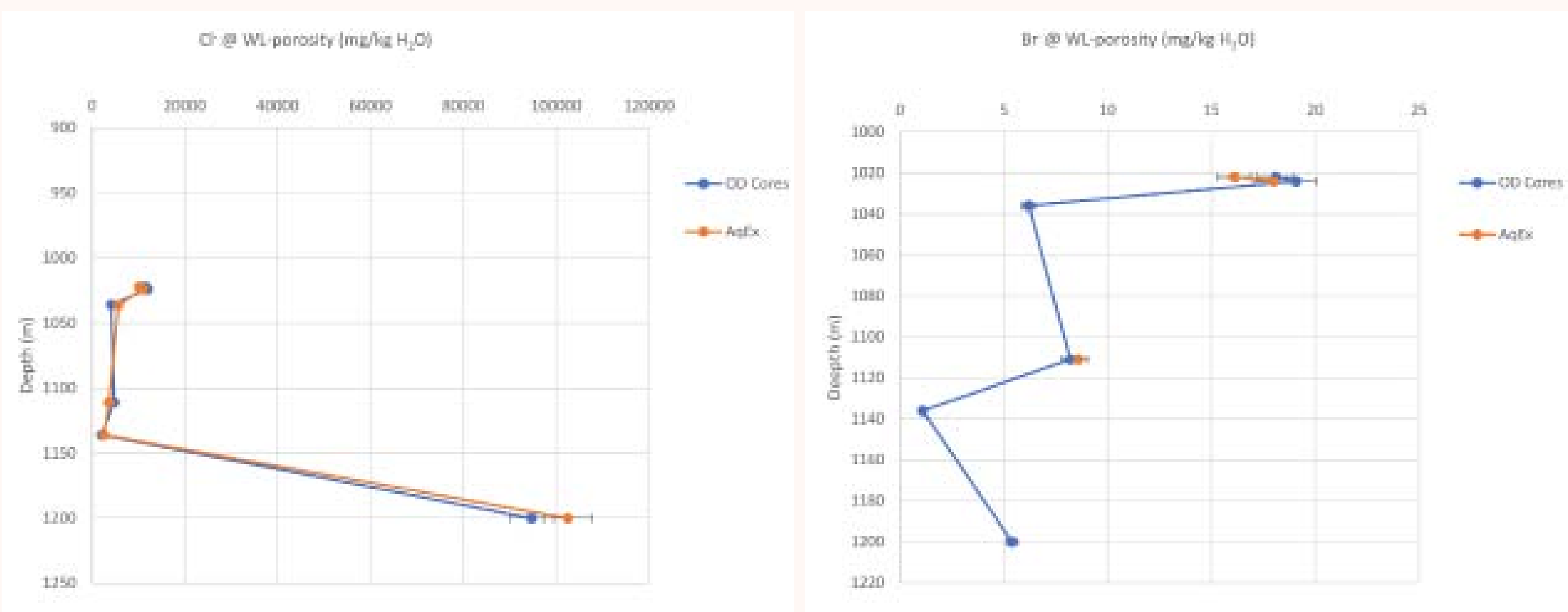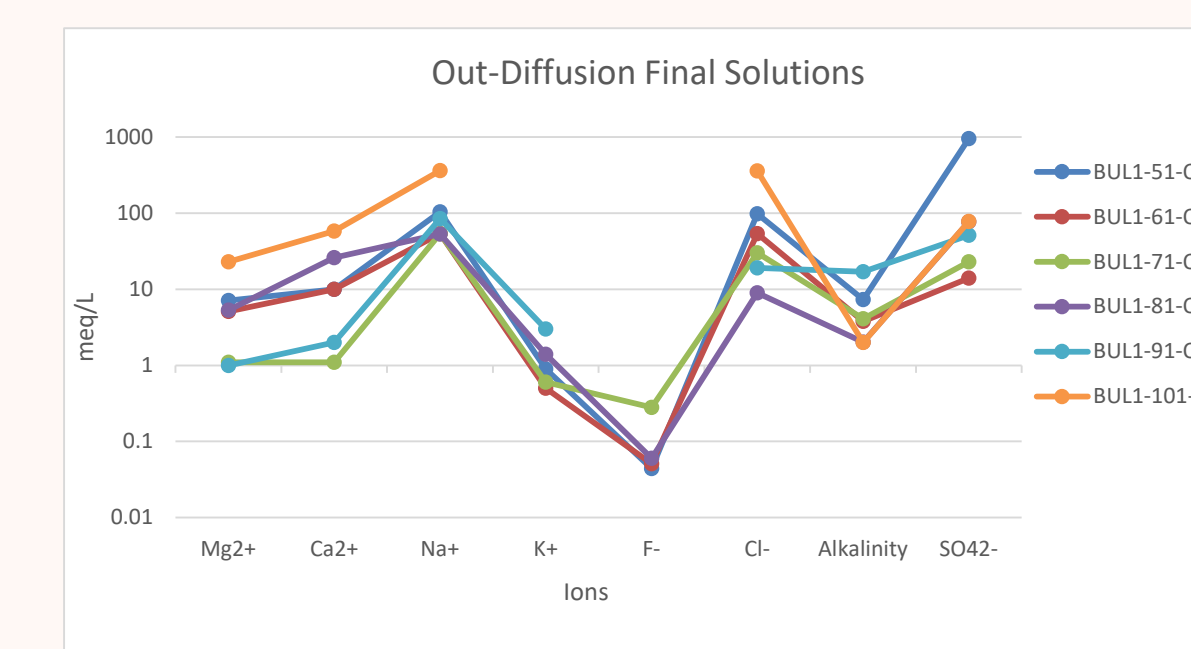

Figure 6: Cl^- and Br^- concentration at WL-porosity versus depth

Porewater Characterization

Final Solutions	Chemical Type
BUL1-51-OD	Na-Cl(SO$_4$)
BUL1-61-OD	Na-Cl-SO$_4$
BUL1-71-OD	Na-Cl-SO$_4$
BUL1-81-OD	Na-SO$_4$-Ca(Cl)
BUL1-91-OD	Na-SO$_4$-Cl
BUL1-101-OD	Na-Cl(SO$_4$-Ca)

Figure5: IC analysis of Out-diffusion Final solutions reveals ionic concentrations from which the chemical types of solutions can be derived; mostly Na-Cl-(SO4)
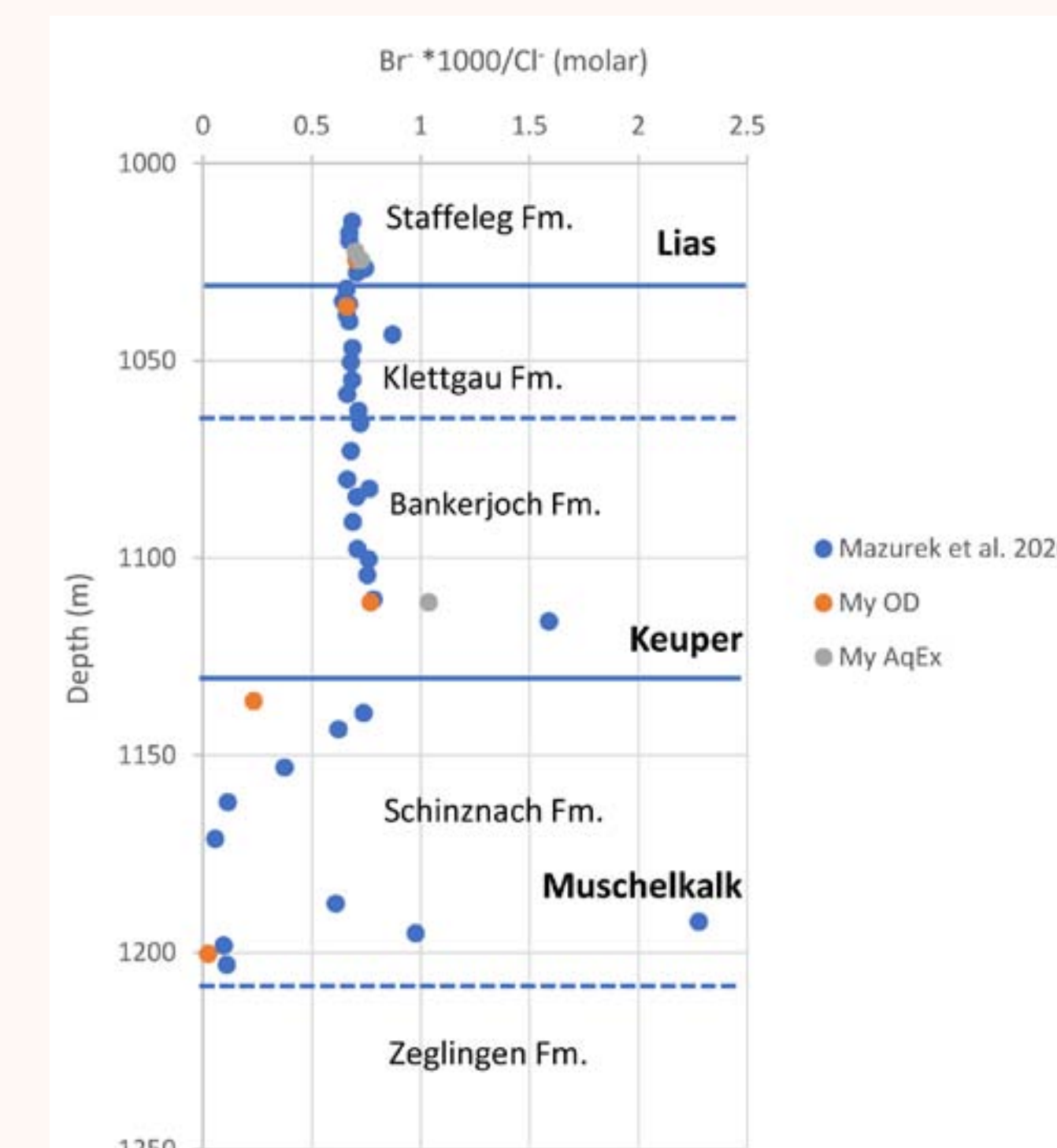

Figure 7: Br*1000/Cl porewater composition obtained from out-diffusion compared to those of Mazurek et al. 2020

Observation: This ratio gives information about salinity and origin of wate. Here a change of ratios in Keuper compared to Muschelkalk suggests a different origins for the two waters.

Summary and Outlook

It is possible to extract chemical porewater compositions of sedimentary rocks by out-diffusion and the results are compatible with those obtained by aqueous extraction. Cl^- and Br^- concentrations at WaterLoss-porosity from Out-Diffusion and Aqueous Extractions agree with the analytical uncertainty; indicating that the porewater is essentially the only reservoir for Cl^- and Br^- in destructive Aqueous Extraction tests.
Future work must be perfored on IC results to correct for the Cl^- concentration of the collected 0.5mL subsamples and to derive by modelling the pore diffusion coefficients for Cl^- and Br^-. Moreover, calculations of porewater stable isotope composition by mass balance is needed.

References
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