Modelling and measuring density-driven hydraulic and reactive processes in karst systems

Advisor(s)

Holger Class, Department of Hydromechanics and Modelling of Hydrosystems

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density-driven enhanced dissolution, CO_2, carbonate rock, reactive transport, Navier-Stokes equation, Darcy equation, numerical modelling, measurements

Introduction / Background

Karst systems are found in many parts all over the world, e.g. [4]. They are characterized by the dissolution of carbonate rocks in the presence of carbonic acid. The CO_2 to replenish the dissolution potential of waters in contact with the rock is produced in the soil by microbes that degrade organic matter. Classical textbook explanations require mobile meteoric water that takes up CO_2 during the passage of the soil zone. This leads to denudation of the karst landscape but can also lead to corrosion deep in the rock due to mixing corrosion, when two (or more) water streams mix [1]. Mixed water is always carbonate-aggressive. Only recently, it was proposed that replenishment of CO_2 deep inside karstic waters can occur also via a mobil gas phase even without percolating meteoric water [2]. Density-driven enhanced dissolution can take place at the karst-water table, even if it is stagnant, and convective mixing inside the stagnant water body is an efficient transport process for CO_2 from the gas phase into the water. Thus, this so far in the literature unaddressed process may contribute to speleogenesis and further research is required to quantify how big such a contribution may be and under which conditions it is relevant [2,3].

Evtl. Research Environment (Einbettung in die jeweilige bereits existierende Forschungsgruppe)

The research is embedded in currently three projects which are all funded by the German Research Foundation (Deutsche Forschungsgemeinschaft – DFG) and related to the Collaborative Research Cluster 1313 (Interface-driven multi-field processes in porous media – flow transport and deformation) and to the SimTech Cluster of Excellence (EXC 2075).

EXC 2075: Coupled flow, transport, and geochemical processes in fractures/fissures with a focus on geothermal and karstic systems

DFG, CL 190/4-1 Experimental and numerical investigations on density-driven dissolution of CO_2 and related carbonate dissolution in karst water

SFB 1313, C04 Pore-scale and REV-scale approaches to biological and chemical pore-space alteration in porous media

Research goals

The overall aim of this research is an assessment of the relevance of two fundamental processes for speleogenesis: (i) gas-phase transport of CO_2 in the soil zone and the epikarst region, and coupled with that (ii) density-driven enhanced dissolution (convective mixing) in karst-water bodies (stagnant or at very small flow velocities).

Therefore, it is planned to address long-term effects on karst dissolution rates based on the results of currently ongoing related projects (see above).

Methods to be used

Numerical modelling using Dumux (www.dumux.org) or other suitable software packages (e.g. OpenFOAM), experimental (field and lab) measurements as required and dependent on funding

References

[1] Bögli, A.: Karst Hydrology and Physical Speleology, Springer Berlin Heidelberg, 1980

[2] Class, H., Bürkle, P., Sauerborn, T., Trötschler, O., Strauch, B., Zimmer, M.: On the role of density-driven dissolution of CO2 in phreatic karst systems, Water Resources Research 57, e2021WR030912, 2021

[3] Class, H., Weishaupt, K., Trötschler, O.: Experimental and simulation study on validating a numerical model for CO2 density-driven dissolution in water, Water 12, 738, 2020

[4] Ford, D.C., Williams, P.W.: Karst Hydrogeology and Geomorphology, Wiley, 2007

Prerequisites

The position requires very good background in computational fluid mechanics and programming. Good knowledge of geochemistry is also highly appreciated.