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Density-induced CO₂ dissolution - approaches to test a new hypothesis on a process relevant for epigenetic karstification

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A process which has not yet been discussed as relevant for epigenetic karstification in phreatic zones has been hypothesized in a publication by Scherzer et al. (2017). It refers to an enhanced CO₂ transport into the phreatic zone by density-induced convective dissolution. The phenomenon is well-known also in CO₂ geologic sequestration and is denoted there typically as solubility trapping. Scherzer et al. (2017) denote this process in caves as nerochytic speleogenesis (from nerochytic = sink in Greek), assuming it has relevance for epigenetic karstification under certain circumstances. This could be relevant in particular in caves where CO₂ concentrations are highly elevated and show strong seasonal fluctuations.

Thomas et al. (2015) have introduced a method to visualize fingering patterns of CO₂ convective dissolution in water with a pH-sensitive color indicator. We have used this approach to produce a set of experimental data in a laboratory flume of dimensions 60 cm x 40 cm x 1 cm. Our aim is to validate a numerical model that we implemented in the simulator DuMu^x (www.dumux.org), which can later on be used for future studies as the basis for investigating the relevance of nerochytic speleogenesis for karstification.

We have applied atmospheres with varying concentrations of carbon dioxide as boundary conditions at the top of the flume and observed the onset times and fingering patterns, in particular we focused on the velocity of the fingers.

The Navier-Stokes model with water density dependent on CO₂ concentration is run in 2D, 3D and pseudo 3D, the latter referring to a 2D approach with a drag term in the momentum balance to account for wall friction at the front and the back plate. Without calibration or fitting of parameters, the results of the comparison between experiment and simulation show reasonable agreement both with respect to the onset of convective fingering and the number of fingers occurring.

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