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Evaluating the role of hydrostatic gradient and structural dip on subsurface dissolution of evaporites

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Typically, four basic requirements are defined for subsurface dissolution of salt (NaCl), or gypsum ($CaSO4$): (1) a deposit of salt or gypsum against which, or through which water can flow, (2) a supply of water undersaturated with NaCl, or $CaSO4$, (3) an outlet where the resulting brine can escape, and (4) energy, such as provided by a hydrostatic head, or density gradient, which causes groundwater flow through the system. Based on an approximately 1000m long, and 150m deep 2D field scale model, which represents a setup of two aquifers connected by subvertical fault zones, a series of 2D density-coupled solute transport simulations were conducted. Hydraulic boundary conditions were assigned according to a regional 3D groundwater flow model. The maintained hydrostatic gradient in the 2D model section is a result of both a natural hydrostatic gradient and a superimposed anthropogenic large-scale groundwater withdrawal in the upper aquifer. A numerical model based on Mixed Finite Elements for the fluid flow problem and a combination of Discontinuous Galerkin Finite Element and Multi-Point Flux Approximation methods for the transport turned out to be adequate for the simulation of density driven flow. Results indicate that the upconing process of saline groundwater from the deeper aquifer above the halite formation to the upper aquifer occurs under different sets of subsurface parameter constellations and hydraulic boundary conditions. Steady-state of the concentration distribution in the upper aquifer is reached in most simulations after relative short time span, and increased salinities are affecting most parts of the aquifer. The resulting salinity stratification with increase towards the bottom of the upper aquifer corresponds both to field observation data and measurements in laboratory scale flow tank experiments. Moreover, the effect of the anthropogenic groundwater withdrawal on salt dissolution rate is significantly lower than expected. Considerably more sensitive to the dissolution rate, however, is the structure, or dip of the halite formation. An increase of dissolution rate can be observed with increasing dips. The dissolved salt moves along the dip and initiates a local flow field driven by gravitation which is decoupled from the regional hydrostatic gradient. Therefore, we propose to add structural dip as additional basic requirement for subsurface dissolution of evaporites.