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MODELING THE DIFFUSIVE BEHAVIOR OF HELIUM AND URANINE IN A POROUS/FRACTURED CHALK AQUIFER

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Informative data is needed to understand transport processes in the heterogeneous subsurface. For example, realistic modeling of transport processes in fractured rocks requires information about the fracture network and possible fracture-matrix exchanges. Field experiments involving the use of tracers with different values for the molecular diffusion coefficient are promising for imaging possible fracture-matrix exchanges more accurately and on different time and spatial scales. This can bring complementary data for modeling and support the reconstruction of the porous/fractured medium.

In this context, dissolved gases (helium, argon, and xenon) and uranine were jointly injected into a saturated and porous/fractured chalk aquifer and recovered at a distance of 7.55 m (convergent test) or in the injection well after a specific ‘resting time’ (push-pull). For both tests, a sub-horizontal orientated fracture was isolated for injection using an inflatable double packer system. Uranine was measured with a field fluorimeter, and concentrations of the recovered dissolved gases were accurately measured on site with a mobile mass spectrometer. The diffusion coefficient of the tested tracers varies by one order of magnitude, resulting in significantly different breakthrough curves of uranine and helium during the convergent test. Analytical solutions involving multi-fracture and multi-channel conceptualization were used to simulate the experimental observations and to account for diffusion in the rock matrix. Dispersivity, fractures aperture and number, channels radius and number were manually adjusted using the experimental uranine and helium breakthrough curves in residence time distribution (RTD). The difference between observations and simulations was minimized by giving equal weight to the peak value, peak time, and slope in the RTD. For the convergent test, the uranine behavior was realistically simulated with the multi-fracture model, while for helium the multi-channel model was required. In contrast, all push-pull results could be simulated with a multi-fracture model as a smaller volume of porous medium was investigated. In addition, the experimental uranine and helium breakthrough curves of the convergent test were numerically simulated using a 3-dimensional model developed with HydroGeoSphere. Multiple discrete fractures are conceptualized, 3-dimensional diffusion is considered, and parameters are manually calibrated. The experimental data are simulated realistically by considering the contrasted diffusion coefficients of the tracers.

The study demonstrates the potential of higher diffusive tracers and that such informative field data clearly support further modeling of dual media, including the application of innovative predictive approaches with the goal of more robust simulations and predictions.

Reference

- Hoffmann R., Goderniaux P., Jamin P., Chatton E., de la Bernardie J., Labasque T., Le Borgne T. and A. Dassargues, 2020. Continuous dissolved gas tracing of fracture-matrix exchanges. *Geophysical Research Letters* 47(17): e2020GL088944