Stress Effects on Solute Transport in Fractured rocks

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Abstract

The effect of in-situ or redistributed stress on solute transport in fractured rocks is one of the major concerns for many subsurface engineering problems. However, it remains poorly understood due to the difficulties in experiments and numerical modeling. The main aim of this thesis is to systematically investigate the influences of stress on solute transport in fractured rocks, at scales of single fractures and fracture networks, respectively.

For a single fracture embedded in a porous rock matrix, a closed-form solution was derived for modeling the coupled stress-flow-transport processes without considering damage on the fracture surfaces. Afterwards, a retardation coefficient model was developed to consider the influences of damage of the fracture surfaces during shear processes on the solute sorption. Integrated with particle mechanics models, a numerical procedure was proposed to investigate the effects of gouge generation and microcrack development in the damaged zones of fracture on the solute retardation in single fractures. The results show that fracture aperture changes have a significant influence on the solute concentration distribution and residence time. Under compression, the decreasing matrix porosity can slightly increase the solute concentration. The shear process can increase the solute retardation coefficient by offering more sorption surfaces in the fracture due to gouge generation, microcracking and gouge crushing.

To study the stress effects on solute transport in fracture systems, a hybrid approach combing the discrete element method for stress-flow simulations and a particle tracking algorithm for solute transport was developed for two-dimensional irregular discrete fracture network models. Advection, hydrodynamic dispersion and matrix diffusion in single fractures were considered. The particle migration paths were tracked first by following the flowing fluid (advection), and then the hydrodynamic dispersion and matrix diffusion were considered using statistic methods. The numerical results show an important impact of stress on the solute transport, by changing the solute residence time, distribution and travel paths. The equivalent dispersion coefficient is scale dependent in an asymptotic or exponential form without stress applied or under isotropic compression conditions. Matrix diffusion plays a dominant role in solute transport when the hydraulic gradient is small.

Outstanding issues and main scientific achievements are also discussed.

Key Words

Fractured rocks; Solute transport; Stress effects; Coupled stress-flow-transport processes; Analytical solution; Particle mechanics model; Fracture surface damage; Discrete element method; Particle tracking method