DEMIREL Serdar (2018) : Electrical studies infractured media

Abstract

Fractured rocks are of vital importance, since they may contain valuable resources, such as water and hydrocarbons, or may allow the transport of unwanted contaminants and pollutants. Thus, the ability to model and characterize fractured media is of great interest to many different scientific communities. A common geophysical method, used in engineering and hydrogeological investigations to study the near surface, is the geoelectrical method, which has been shown in previous work to be sensitive to fracture characteristics. To further explore the potential use of the geoelectrical method for the characterization of fractured rocks, three main challenges are addressed in this thesis.

A key issue when it comes to estimating fractured-rock characteristics from electrical resistivity measurements is the absence of a suitable and low-computational-cost numerical modeling procedure. Especially, the modeling of discrete 3D fracture networks in an efficient manner remains unresolved. To overcome the computational limitations of conventional finite-difference, -element, or -volume methods, where every fracture must be explicitly discretized, 2D and 2.5D discrete-dual-porosity (DDP) approaches have been recently developed. With these approaches, fractures are represented explicitly as 1D linear elements through a discrete-fracture-network (DFN), the matrix is coarsely discretized into blocks, and the flow of electric charges between fractures and matrix is analytically expressed based on differences in electric potential between these domains. Here, we provide the first building blocks to extend the 2D approach to 3D fracture networks. The corresponding analytical expressions are derived and tested for simple geometries against an established finite-element code. However, several challenges must be addressed in future work.

The second aspect investigated in this thesis concerns the still open question of whether characteristics of the electrical conductivity in fractured rocks might be used as a proxy for information about the hydraulic conductivity. The latter is the sought after property in many practical applications. In order to address this question, numerical simulations on 2D stochastically generated fracture networks are performed. To model electric current flow, a DDP approach is used, whereas groundwater flow is simulated using a standard DFN approach. We analyze if the resulting equivalent tensor properties (anisotropy and the principal orientation of fractures) are consistent for the hydraulic and electrical conductivities and for what size of domain these tensor properties are well represented. The latter represents the concept of a representative elementary volume (REV). The results of our modeling show that the REV size for the electrical conductivity is notably smaller than that for the hydraulic conductivity for a realistic choice of conductivity values. In addition, we observe that significant differences between the sensitivity of fluid and electric current flow to fracture aperture can lead to strong discrepancies in tensor characteristics and the corresponding REV sizes. We thus conclude that great care must be taken when attempting to infer information regarding the hydraulic conductivity tensor from field electrical resistivity measurements in fractured-rock environments.

Finally, we conduct a systematic study in which we evaluate the effect of a single buried fracture on ER-profiling data, examining how the corresponding anomaly changes as a function of the fracture and domain characteristics. The Wenner-Schlumberger and Dipole-Dipole arrays, are considered in our analysis with different spacing factors. Depending on the considered electrode array configuration, we observe that the fracture dip angle and length will impact the resistivity anomaly curves differently, with the Wenner-Schlumberger array being better adapted for distinguishing between sub-horizontal and sub-vertical fractures.