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Characterizing Fractured Rock with Geo-structural and Micro-structural Models

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Fracture spatial structure and hydro-mechanical properties are key to the understanding of fractured rock geomechanical stability, hydrodynamics, and solute transport. This paper presents a quantitative approach to fracture characterization to provide information useful for stability and flow analysis, and for coupled flow/geomechanics. The approach presented is based on the concept of geo-structural, hydro-mechanical, and microstructural models. This approach is applicable for data collected from exposed surfaces (mapping, LiDAR, aero-magnetics), boreholes (core, optical images, and images based on resistivity and geophysical methods), and three dimensional imaging (seismic attributes and microseismics). Examples are presented comparing the results of conventional fracture characterization procedures and the recommended procedure.

Fracture characterization for geo-structural fracture models is based on the idea that the geologically based fracture spatial pattern is the key, rather than individual fracture statistics. For example, while fracture intensity statistics can useful, the three dimensional fracture pattern for a bedded sedimentary rock can be better reproduced from the combination of a mechanical bedding model and a correlation between fracture spacing and bed height.

In a fracture geo-structural model, the fracture spatial pattern, orientation, and intensity should be characterized in a combination of global and local coordinate systems. While some fracture sets may be oriented relative to the regional tectonics (the global coordinate system), other fracture sets are oriented relative to bedding (a local coordinate system).

Fracture hydro-mechanical models define the combination of (a) conductive fractures, (b) flow-barrier fractures, (c) fractures which provide storage porosity, (d) fractures of significance for kinematic stability, and (e) fractures of significance for rock mass strength and deformability. The hydromechanical fractures are a subset of the fractures in the geo-structural model. The hydro-mechanical model adds hydraulic properties such as of roughness (channeling), permeability (transmissivity), storage aperture, mechanical properties such as shear strength, dilation angle, fracture toughness, shear and normal stiffness, and mechanical aperture (roughness). As in the geo-structural approach, hydro-mechanical models require characterization of the relationships between fracture geometry and fracture properties, rather than simple statistical characterization of populations of (for example) fracture transmissivity. The hydro-mechanical model characterization approach concentrates on measurements that support the development of correlations between e.g, fracture size and transmissivity, or fracture orientation and shear strength.

Fracture microstructural models describing fracture internal structure are the fundamental building block for hydro-mechanical models. Geologists know well that fractures are not just disks or planes in space. Each fracture has a degree of internal structure such as infillings, asperities, fracture coatings, and may be composed of many individual surfaces which combine together to define the fracture or fault at the larger scale. The approach developed in this paper therefore presents procedures for characterization of this internal structure, as the basis for hydro-mechanical properties.