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Flow of Fractured Rock; 1.1. Introduction; 1.2. Approaches to modelling rock systems; 1.3. Continuum models; 1.4. Flow models; 1.5. Discontinuum models; 1.6. Overview of UDEC; 1.7. Summary of numerical modelling; Chapter 2. Modelling of Simple Rock Blocks; 2.1. Introduction; 2.2. Basic components of natural fracture networks; 2.3. Model geometry and initial conditions; 2.4. Basic behaviour of deformation and fluid flow; 2.5. Effects of fracture geometry; 2.6. Effects of fracture properties; 2.7. Effects of applied boundary stresses; 2.8. Effects of rock deformation models; 2.9. Summary; Chapter 3. Evaluation of 2-Dimensional Permeability Tensors; 3.1. Introduction; 3.2. Calculation of components of flow-rates; 3.3. Permeability in naturally fractured rocks; 3.4. Geometrical effects on permeability; 3.5. Effects of stress on permeability; 3.6. Conclusions; Appendix 3-A 1: Input codes for example one; Appendix 3-A2: Derivation of 2-D permeability tensor; Chapter 4. Scaling of 2-D Permeability Tensors; 4.1. Introduction; 4.2. Development of the previous approach; 4.3. Testing the concept of a representative element volume by down-scaling; 4.4. Scaling-up of permeability; 4.5. Effects of sample number and sample size; 4.6. Determining the permeability of a region; 4.7. Conclusions; Chapter 5. Percolation Behaviour of Fracture Networks; 5.1. Introduction; 5.2. Modelling of 2-dimensional fracture networks; 5.3. Density, percolation threshold and fractal dimension; 5.4. Critical behaviour of fractured rock masses; 5.5. Conclusions; Chapter 6. Slip and Fluid Flow around An Extensional Fault; 6.1. Introduction; 6.2. Outline of modelling; 6.3. Stress distribution and fluid flow in model A: At a shallow depth with a hydrostatic fluid pressure; 6.4. Comparison of model A with a supra-hydrostatic fluid pressure at greater depth; 6.5. Effects of irregularities in fault zone; 6.6. Discussion of dynamic response of fluid-dilation interactions; 6.7. Conclusions; Chapter 7. Instability and Associated Localization of Deformation and Fluid Flow in Fractured Rocks; 7.1. Introduction; 7.2. Numerical determination of instability; 7.3. Instability and R-ratio; 7.4. Effects of fracture network geometry; 7.5. Multifractal description of flow localisation; 7.6. Permeability of three natural fracture networks before and at critical stress state; 7.7. Effects of loading direction; 7.8. Is the crust in a critical state?; 7.9. Implications for mineral deposits; 7.10. Conclusions; Chapter 8. Grain Scale Flow of Fluid in Fractured Rocks; 8.1. Introduction; 8.2. Simulation of Deformation and Fracturing in Matrix Models; 8.3. Dual Permeability Model; 8.4. Results; 8.5. Discussion and Conclusions; Chapter 9. Changes of Permeability due to Excavation of Ship-Locks of the Three Gorges Project, China

## Sommario/riassunto

Our understanding of the subsurface system of the earth is becoming increasingly more sophisticated both at the level of the behaviour of its components (solid, liquid and gas) as well as their variations in space and time. The implementation of coupled models is essential for the understanding of an increasing number of natural phenomena and in predicting human impact on these. The growing interest in the relation between fluid flow and deformation in subsurface rock systems that characterise the upper crust has led to increasingly specialized knowledge in many branches of earth scienc