Geophysical Research Abstracts,
Vol. 11, EGU2009-7536-1, 2009
EGU General Assembly 2009

Depth and grain size dependency of hydraulic properties of faulted, crystalline rocks - examples from the Austro-Alpine (Eastern Alps, Austria)

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In fractured crystalline aquifers it is generally assumed that matrix conductivity and intergranular porosity are negligible, and that flow occurs within rock mass discontinuities (e.g. the fracture system and fault zones). Water flow is therefore significantly influenced by hydraulic characteristics of the discontinuities, and in particular, faults and fault zones. These zones may represent hydraulic barriers or conduits, or a combination of both, depending on their geological evolution, physical characteristics and the existing in-situ stress regime. Challenges related to hydraulic characterization of faults include their substantial heterogeneity with regard to internal structure, abrupt variations in hydraulic properties, and the significance of inherently limited field-scale data. The investigation area (Semmering region – Lower Austro Alpine in the Eastern Alps) is characterized by a complex tectonic evolution, with fault types varying in zonation, fault rock type, and development of cataclasis.

In concert with recent geologic and hydrogeologic explorations carried out for major infrastructure projects, packer tests with interval lengths between 30 m to 130 m were processed in boreholes with a maximum depth of 300 m below surface. These data include over 120 borehole hydraulic tests and several kilometres of drill core. The packer test intervals include rock formations with various fault zones, fault rock types and within the fault zones various types of cataclasites up to fault gouges. A first rough quantification results a percentage of cataclasite from 0 % up to 80% within the test intervals. Considering the fault rock content there is marked a critical value of about 15 % over which the hydraulic conductivity is constantly lower than 2E-07 m/s. The results from all hydraulic packer tests show hydraulic conductivities from 6,7E-05 m/s to 1,1E-10 m/s.

Additionally, 26 oriented samples of a fault core were taken with steel pipes along a scan line at an exposure. The samples were analysed with respect to their orientation to the fault plane, the grain size distribution, the clay mineral content and the hydraulic conductivity. The hydraulic conductivities were determined by the application of tri-axial cells in the laboratory. The results gave values between 1,7E-07 m/s and 4,2E-11 m/s. The median hydraulic conductivity is approximately 3E-08 m/s. These results are in accordance to the packer tests considering that the taken samples represent just the hydraulic properties of a fault core and are representative for a different scale. The analyses show a dependency of the hydraulic conductivity especially on the content of fine grained particles (clay fraction about 15 % as a critical value) and the orientation of the samples. The samples including more than 15 % fine grained material (mainly clay fraction) differ from the samples with lower than 15 % with a magnitude of approximately 1,5E+01.

The combined analyses of the packer test data and the data of the steel pipe sample analyses in the laboratory result in a critical percentage of about 15 % for fine grained material. The hydraulic conductivities of both test sites are in accordance and the combined analyses of all data show a correlation between decreasing hydraulic conductivities with increasing depth down to 300 m.