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Quantifying porosity and permeability of fractured carbonates and fault rocks in natural groundwater reservoirs

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This study presents porosity and permeability data for a suite of different carbonate rocks from two major groundwater reservoirs in eastern Austria that supply more than 60% of Vienna‘s drinking water. Data includes a set of lithologically different, unfractured host rocks, fractured rocks with variable fracture intensities, and fault rocks such as dilation breccias, different cataclasites and dissolution-precipitation fault rocks. Fault rock properties are of particular importance, since fault zones play an important role in the hydrogeology of the reservoirs.
The reservoir rocks are exposed at two major alpine karst plateaus in the Northern Calcareous Alps. They comprise of various Triassic calcareous strata of more than 2 km total thickness that reflect facies differentiation since Anisian times. Rocks are multiply deformed resulting in a partly dense network of fractures and faults. Faults differ in scale, fault rock content, and fault rock volumes.
Methods used to quantify the porosity and permeability of samples include a standard industry procedure that uses the weight of water saturated samples under hydrostatic uplift and in air to determine the total effective (matrix and fracture) porosity of rocks, measurements on plugs with a fully automated gas porosity- and permeameter using N2 gas infiltrating plugs under a defined confining pressure (Coreval Poro 700 by Vinci technologies), and percolation tests. The latter were conducted in the field along well known fault zones in order to test the differences in fractured rock permeability in situ and on a representative volume, which is not ensured with plug measurements. To calculate hydraulic conductivity by the Darcy equation the measured elapsed time for infiltrating a standard volume of water into a small borehole has been used.
In general, undisturbed host rock samples are all of low porosity (average around 1%). The open porosity of the undisturbed rocks belonging to diverse formations vary from 0.18% to 2.35%. Klinkenberg permeabilities of plugs range from 0.001mD to about 0.6mD thus spreading over three orders of magnitude.
Fractured rocks show significantly higher porosities (3% average) with respect to the undeformed country rocks. Plug measurements reveal quite low permeabilities (< 1mD) for this type of rock, which is owed to the measuring technique, where fractures are closed under confining pressure. A second important point is that intensely fractured rocks are underrepresented in the data as they cannot be plugged adequately. Percolation tests give better information for fractured rock permeabilities and revealed hydraulic conductivities of 10-6 m/sec for little fractured to 5x10-5 m/sec for intensely fractured rocks.
Plug and rock sample data show that cataclastic fault rocks can have quite high porosities (up to 4.1%). However, plug permeabilities down to 0.03mD demonstrate that pores are too small to result in any significant permeability. Breccias show high porosities of 4% in average and very variable permeabilities between 2.2mD and 2214mD depending mainly on the degree of cementation.