The modification of rock mechanical characteristic values during the formation of fault rocks

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Faults are of major interest both in structural geology, tectonics, in engineering geology and rock mechanics. The interest in faults and fault zones is practical as well as scientific and aestethic due to the following reasons:
Faults and associated structures form the major discontinuities in the Earth´s upper crust and are largely responsible for the design and shape of the great mountain belts. Understanding faults is useful in the design for long-term stability of dams, tunnels, buildings, and power plants, as well as for their effect on population centers and infra-structure. Study of faults helps in understanding mountain-building and deformation processes – studies that have many times turned out to have practical value.
Faults are extraordinarily important in rock engineering. The extreme complexity of faults makes their geotechnical investigation and characterization difficult. The technical problems related to faults include their substantial heterogeneity with regard to the internal structure, mineralogical composition, mechanical and hydrological properties as well as stress distribution. In this study, we focus on faults and related fault rocks that formed in the upper crust (i.e., above the brittle-ductile transition), mainly by fracturing of the host rock ("cataclasis"), and on related brittle structures. The occurrence of these rocks highly influences the mechanical properties of the rock mass as a whole and generally results in weakening as well as failure along pre-existing fracture zones. We investigate the continuous evolution of a major fault within an Alpine-type orogen from its margin towards its core, i.e., from the host rock(s) to the fault rock(s), and the mechanisms behind, its structural, chemical and mechanical changes (e.g., shear resistence). In particular, this study focusses on

- the rock mass strength and deformability, depending on parameters like grain shape, grain size distribution, mineralogical composition of the fault rocks (in particular of the clay minerals), the density and geometric pattern of the shear fractures and the extent of the fault zone as a whole;
- the rock mass permeability, ranging from localized/distributed conduit (preferred aquifer) over combined conduit – barrier systems to complete barriers.

For a case study we have chosen the Koralm Massif in the Eastern Alps. The Koralm Massif is bordered by major confining faults along its western margin (the Lavanttal Fault system), and along its eastern margin. Thus, the Koralm Massif exposes a well situated testing area providing the elaboration of the relationships between faulting along the margins of the Koralm Complex, brittle structures in the internal parts, as well as the investigation of the structural evolution of a major fault zone (the Lavanttal Fault) and the related fault rocks. This area has been chosen because of our wide knowledge of this part of the Eastern Alps due to own field studies, and because the Koralm Tunnel with a length of 32.8 km is planned to be built under the Koralm Massif between Deutschlandsberg and St. Andrä south of Wolfsberg, providing access to additional outcrops and essential sample material.

Small-scale mapping of the lithology and macroscopic (brittle) structures, and the detailed investigation of representative outcrops (e.g., scan-line-mapping) gives detailed information about the geometry of the joint system, and the properties of distinct joint sets (e.g., aperture, width, length, roughness, filling,…). Based on these data, certain domains were defined, each being characterised by a particular hydraulic effectivity.

This work provides the compilation of hydrogeological parameters (e.g., permeability, porosity, etc.) based on a detailed tectonic analysis. This is a major input for numeric-hydraulic modelling.

Seismic studies on drill cores include the measurement of the velocities of ultrasonic waves for the calculation of the elastic parameters of the rock materials; this provides additional information on the development of an anisotropy during continuous deformation and grainsize reduction due to fracturing (i.e., from the proto- to the ultra-cataclasite). Moreover, an increase of the number of microstructures is assumed to result in a decrease of both ultrasonic wave velocities and the penetrability for sonic waves. These parameters can be used as an estimate for weakened rock mass, and as an index indicating that a fault zone is to be approached.

Rock mechanic tests including uniaxial compressive (quasi-) triaxial tests and line-load tests in order to determine the basic elastic constants, and direct-shear tests so as to investigate the impact of grain size distribution, mineralogy and structure of fault rocks on their shear behaviour. The physical properties determined in this way can be used for the estimation and (numerical) modelling of the in-situ shear resistance and deformation behaviour of individual shear planes (with /without gouge fillings) and the faulted rock mass as a whole.