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Fracture distribution and porosity in a fault-bound hydrothermal system (Grimsel Pass, Swiss Alps)

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The spatial distribution, orientation and continuity of brittle and ductile structures strongly control fluid pathways in a rock mass by joining existing pores and creating new pore space (fractures, joints) but can also act as seals to fluid flow (e.g. ductile shear zones, clay-rich fault gouges). In long-lived hydrothermal systems, permeability and the related fluid flow paths are therefore dynamic in space and time. Understanding the evolution and behaviour of naturally porous and permeable rock masses is critical for the successful exploration and sustainable exploitation of hydrothermal systems and can advance methods for planning and implementation of enhanced geothermal systems. This study focuses on an active fault-bound hydrothermal system in the crystalline basement of the Aar Massif (hydrothermal field Grimsel Pass, Swiss Alps) that has been exhumed from few kilometres depth and which documents at least 3 Ma of hydrothermal activity. The explored rock unit of the Aar massif is part of the External Crystalline Massifs that hosts a multitude of thermal springs on its southern border in the Swiss Rhône valley and furthermore represents the exhumed equivalent of potentially exploitable geothermal reservoirs in the deep crystalline subsurface of the northern Alpine foreland basin. This study combines structural data collected from a 125 m long drillhole across the hydrothermal zone, the corresponding drill core and surface mapping. Different methods are applied to estimate the porosity and the structural evolution with regard to porosity, permeability and fracture distribution. Analyses are carried out from the micrometre to decametre scale with main focus on the flow path evolution with time. This includes a large variety of porosity-types including fracture-porosity with up to cm-sized aperture down to grain-scale porosity. Main rock types are granitoid host rocks, mylonites, paleo-breccia and recent breccias. The porosity of the host rock as well as the cemented paleo-hydrothermal breccia is typically very low with values <1%. The high volume of mineralized fractures in the paleo-breccia indicates high porosity in former times, which is today closed by newly developed cements. The preservation of such paleo-breccias allow the investigation of contrasts between the fossil porosity/permeability and the present day active flow path, which is defined by fracture porosity that generally follows the regional deformation pattern and forms a wide network of interconnected fractures of variable orientation.