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A natural example of fluid-mediated brittle-ductile cyclicity in quartz veins from Olkiluoto Island, SW Finland

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Brittle faults are well known as preferential conduits for localised fluid flow in crystalline rocks. Their study can thus reveal fundamental details of the physical-chemical properties of the flowing fluid phase and of the mutual feedbacks between mechanical properties of faults and fluids. Crustal deformation at the brittle-ductile transition may occur by a combination of competing brittle fracturing and viscous flow processes, with short-lived variations in fluid pressure as a viable mechanism to produce this cyclicity switch. Therefore, a detailed study of the fluid phases potentially present in faults can help to better constrain the dynamic evolution of crustal strength within the seismogenic zone, as a function of varying fluid phase characteristics.

With the aim to 1) better understand the complexity of brittle-ductile cyclicity under upper to mid-crustal conditions and 2) define the physical and chemical features of the involved fluid phase, we present the preliminary results of a recently launched (micro)structural and geochemical project. We study deformed quartz veins associated with brittle-ductile deformation zones on Olkiluoto Island, chosen as the site for the Finnish deep repository for spent nuclear fuel excavated in the Paleoproterozoic crust of southwestern Finland.

The presented results stem from the study of brittle fault zone BFZ300, which is a mixed brittle and ductile deformation zone characterized by complex kinematics and associated with multiple generations of quartz veins, and which serves as a pertinent example of the mechanisms of fluid flow-deformation feedbacks during brittle-ductile cyclicity in nature. A kinematic and dynamic mesostructural study is being integrated with the detailed analysis of petrographic thin sections from the fault core and its immediate surroundings with the aim to reconstruct the mechanical deformation history along the entire deformation zone. Based on the observed microstructures, it was possible to recognize three distinct episodes of ductile deformation alternating with at least three brittle episodes.

Preliminary fluid inclusion data show that, during crystallization and brittle-viscous deformation, quartz crystals hosted homogeneous and heterogeneous (boiling) aqueous fluids with a large salinity (11.7-0 wt% NaCleq) and Thtot (410-200 °C) range. Boiling occurred at 200-260 °C. Variations of fluid temperature and density (hence, viscosity) may thus have induced localized cyclic switches between brittle and ductile deformation in quartz, with implications on the bulk regional crustal strength. Preliminary EBSD analysis also supports the hypothesis of cyclic switches between brittle and viscous deformation.