

Understanding the seismic cycle in hydrothermal conditions. From innovative experiments and analysis to geochemical modeling

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Earthquakes often originate and evolve in environments characterized by the circulation of fluids at hydrothermal conditions ($150^{\circ}\text{C} < T < 450^{\circ}\text{C}$ and $P_f > 25 \text{ MPa}$). Geophysical research has shown that these fluids play a crucial role in fault mechanics by modifying rock properties and pore pressure. These interactions trigger complex processes such as sub-critical crack propagation, mineral dissolution and precipitation, and fault healing and sealing. However, the knowledge of these mechanisms remains limited due to experimental challenges and timescales of fluid-rock reactions.

The SCHOTTA project (The Seismic Cycle under HydrOThermal conditions: experimenTAl, analytical and modeling studies), funded by the European Union - Next Generation EU - PRIN 2022, is designed to address these gaps. Our multidisciplinary approach integrates:

- innovative laboratory experiments on rock friction, conducted under high temperature and pressure conditions, including water in liquid, vapor, and supercritical state;
- geochemical and mineralogical investigations of both fluids and rocks, analyzed before and after deformation experiments;
- geochemical modeling, calibrated on petrographic, analytical, and chemical data to simulate fluid-rock interactions over time and extrapolate experimental findings to natural fault systems.

A significant challenge in this research is the need for accurate model calibration at extreme conditions, as the most widely used geochemical software is constrained to sub-critical water environments ($T < 300^{\circ}\text{C}$, $P_f < 8.6 \text{ MPa}$).

Through this approach, we found that the physical state of the water and the degree of alteration of the rock have a profound impact on the friction response.

From a geochemical point of view, the first project results show no XRD and XRF significative variations in mineral assemblage, after more than 125 hours of experiments, as a function of hold and duration. Water chemistry changes in

response to mechanical and chemical processes, but also due to apparatus contamination. Textures in the experimental samples are modified along the sliding surfaces where the blocky grains are significantly reduced in size and become rounded, whilst sheet-like crystals align based on the shear. Mechanical compression likely reduces porosity and permeability, fluid circulation with probable element re-distribution.