Faster alteration of rocks in active faults ?

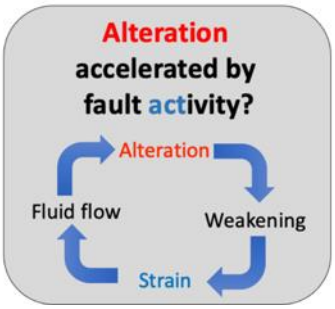
Insight from experiments and numerical simulations, with application to geothermal energy

PhD information

To be held in ISTerre, Grenoble France
(#18 in 2023 Shanghai thematic ranking for Earth Sciences)
under the supervision of Mai-Linh Doan and Frédéric Donzé
Fully Funded for 3 years (starting October 1st, 2024)

PhD topics

The project focuses on the process **of maturation of active faults in the upper crust by chemical alteration of their fault walls, and on the feedback between alteration and tectonic activity.** This topic is at the center of the AlterAction ANR project (https://anr-alteraction.osug.fr/)) gathering 20 scientists from four institutions funded for 42 months (2024-2027).



The main research hypothesis is that fault activity induces new fractures that enhance fluid-rock interactions and the associated fault zone alteration. This feedback forcing would accelerate the maturation of active faults by creating clay gouges that weaken the fault and decrease its core permeability over time. Such a process could also deteriorate the flow properties in **Enhanced Geothermal Reservoirs**, such as in Alsace, which is also a place of active tectonics. Therefore, a better understanding of the coupling between damage and alteration in active faults and reservoirs is required.

Our focus is on granitoid rocks, which are the lithology of both the **Rhine Valley geothermal reservoirs** and the wall rocks of the Nojima fault responsible for the 1995 Nanbu **Kobe earthquake** in Japan. Dynamic loading will pulverize granitoid rocks from both study sites, which enhances their permeability. This facilitates the laboratory alteration of centimetric samples, as shown by preliminary experiments (Fig. 1). Experiments and numerical simulations can then be used to test the main research hypothesis.

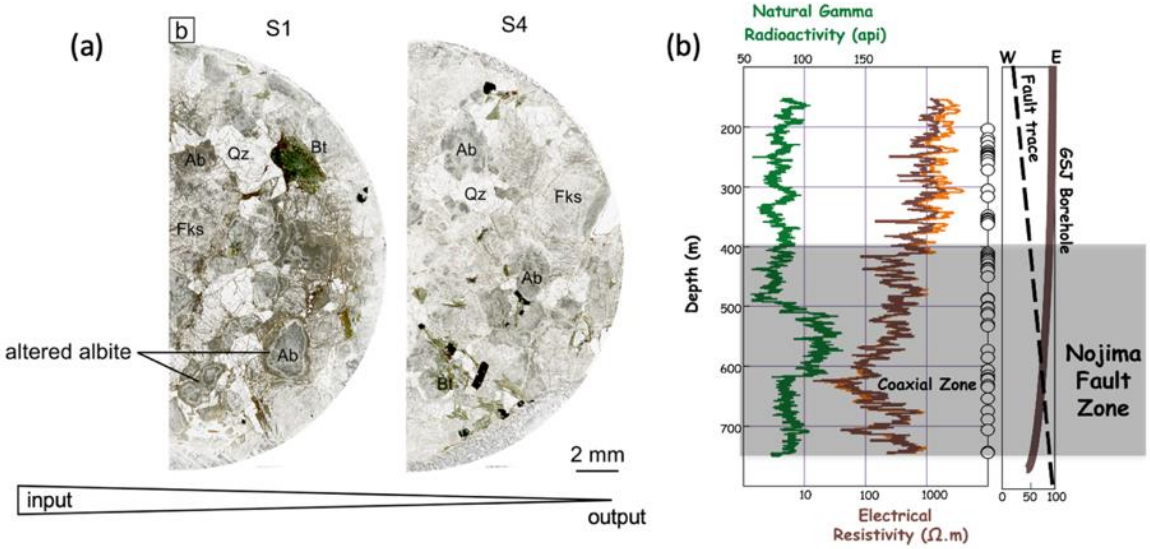


Figure 1. Alteration in the lab and in the field. (a) Thin section showing the alteration gradients generated in a pulverized granite sample during a percolation experiment. (b) Borehole geophysical data along the GSJ Hirabayashi borehole intersecting the Nojima fault, at the origin of the 1995 Kobe earthquake. The strong decrease in electrical resistivity reflects an increase in the alteration when approaching the coaxial zone.

Methods

The study to be undertaken by the PhD laureate is twofold:

1. **Experimental investigation of the influence of deviatoric stress on rock alteration** Several weeklong experiments at various deviatoric stresses will be conducted on the newly upgraded triaxial percolation cells of the ISTerre laboratory, on which preliminary alteration experiments were successful (Fig.1). Stress, strain, permeability, and fluid geochemistry wil be recorded during the experiments. X-ray CT scans will quantify the changes in the fracture network induced by fluid percolation. A possible extension of the experiments may be performed at the European Synchrotron Research Facility (ESRF), for which a CHRONOS proposal was submitted to perform time-lapse X-ray imaging of the sample during the alteration experiments.
2. **Numerical simulations of the alteration and deformation of rocks subjected to deviatoric stress** when percolated with reactive fluids. The simulations will be validated by reproducing the experimental results. Modelling will be used to upscale the experimental results to natural faults and geothermal reservoirs to reproduce the increase in damage and alteration when approaching the fault core, as observed along faults (Fig.1).

Collaboration

The PhD student will benefit from the research network of the AlterAction ANR Project. Especially, he/she will strongly collaborate with another PhD student from Montpellier University, who is in charge of quantifying damage and alteration along the Nojima fault zone, using samples from the GSJ-Hirabayashi borehole to get mineralogical observations and petrophysical measurements.
Although the PhD topic is dedicated to fundamental research, the PhD student will have the opportunity to interact with representatives of the geothermal companies that expressed their interest in the project at the time of its submission.

Contract information

Salary: Gross remuneration is a minimum of €2135.00 per month. Additional teaching is possible and will be remunerated.
The contract spans 3 years

Requirements

The candidate should have a good knowledge of rock mechanics and an appetency for experimental work. Previous experience in numerical modeling is recommended.

Within the framework of the AlterAction ANR project, the PhD student will interact with many researchers in different fields, and open-mindedness and communication skills will be a great bonus.

How to apply

The candidate should contact Mai-Linh Doan (mai-linh.doan@univ-grenoble-alpes.fr) and Frédéric Donzé (frederic.donze@univ-grenoble-alpes.fr) to send:

- Their CV
- A motivation letter

Websites for additionnal information

https://adum.fr/as/ed/voirproposition.pl?langue=&site=edtue&matricule_prop=55531
http://anr-alteraction.osug.fr/