Dipartimento di Scienze della Terra
Sapienza Università di Roma

Dottorato di Ricerca in Scienze della Terra

1. Research activity:

INTEGRITY: fr**I**ctio**N** – s**T**ability – h**E**alin**G** and pe**R**meab**I**li**TY** of simulated basalt faults and implications for CO_2 storage

Abstract:

Underground injection of CO_2-rich water into basaltic reservoirs is one of the most appealing options for CO_2 sequestration. This method provides permanent and safe CO_2 storage in extremely short amount of time: more than 95% of the injected carbon in the CarbFix pilot project (Iceland) was trapped into carbonates in less than 2 years. However, to apply this method also to commercial scale, a thorough assessment of the induced seismic potential stemming from this technique is critical. In this regard, laboratory frictional experiments will be performed to determine the coupled frictional and hydro-mechanical properties of basalts, i.e., fault strength, stability, healing, and permeability.

Rationale and relevance of the project:

Frictional instabilities are the main responsible for earthquakes nucleation (*Brace & Byerlee, 1966*), which generally occur along pre-existing faults and fractures (*Scholtz, 2002*).
So far, only a few set of experiments have attempted to investigate the behaviour of lab-scale faults to injection of pressurized CO_2 (in anhydrites, e.g., *Samuelson & Spiers, 2012*) and H_2O+CO_2 fluid mixtures (in intact basalts cores potentially acting as cap-rocks, exhibiting different degree of alteration, *Giacomel et al.*, 2018, *Geophysical Research Letters*). However, to date the frictional strength with cumulated slip, the friction constitutive parameters as well as the healing properties of faults cross-cutting basalts remain still largely unknown.

Therefore, this PhD project is aimed to determine the friction parameters of dense basalts, at the typical CarbFix-site P, T conditions (i.e., pCO_2 = 2.5 MPa, T = 20-30°C), which govern the nucleation of the frictional instabilities and the mode of fault slip. This is the *sine qua non* for an in-depth assessment of the induced seismic potential and for an effective appraisal of the seismic hazards and risks caused by this storage method.

Research methodology and approach:

1) SAMPLE PROVISION

Basaltic specimen from Mt. Etna with effective porosity < 5% were provided by local quarries. The samples were subjected to a robust pre-experiment chemical (X-Ray Fluorescence), mineralogical (X-Ray Powder Diffraction), petrological (thin sections), petrophysical (effective porosity using the helium pycnometer and pre-experimental Vp/Vs as a frame of reference), and microstructural (Scanning Electron Microscopy) characterization, at the laboratories available at the University “La Sapienza”, INGV- Rome, and Padua University.

2) SHIVA (Slow to HIgh Velocity Apparatus) EXPERIMENTS

To evaluate the evolution of frictional properties of basalt-built faults with cumulative slip and as a result of fluid injection during multiple simulated seismic cycles, experiments will be performed at constant shear displacement rate and using an unconventional technique that allow us to control the shear stress, respectively (i.e., to work under constant shear stress). Notably, in the second suite of experiments, fluid pressure will be increased stepwise up to induce frictional instability during a single seismic cycle, following the experimental protocol pointed out in Giacomel et al., 2018. To account for the diffusion times required to uniformly pressurize the experimental faults, permeability tests have been preliminary carried out on single macro-fractured basalts at the effective stress conditions reached during the friction tests.

The results will be directly relevant to understand the evolution of the seismicity potentially occurring in CO_2 storage reservoirs.

3) BRAVA (Brittle-Rock investigation Versatile Apparatus) EXPERIMENTS

To characterize the mode of fault slip and healing properties of basalt-built faults, the retrieval of laboratory-derived constitutive law for rock friction (e.g. rate and state friction law, *Dieterich, 1979*), is critical. In this regard, experiments will be run at room temperature and shear velocities from 0.1-300 μm/s on bare rock surfaces and powdered basalt specimens, to address the nucleation phase of dynamic slip. Investigated bare surfaces and gouge have a ~ 4 X 4 cm^2 nominal area and ~ 1 cm thickness as in *Tesei et al., 2014*, and ~ 5 X 5 cm^2 nominal area, respectively. Samples were sheared under dry and water-saturated conditions to investigate the friction parameters at atmospheric pressure.

2. Research products

a) Publications (ISI journals)

Giacomel, P., Spagnuolo, E., Nazzari, M., Marzoli, A., Passelegue, F., Youbi, N., & Di Toro, G. (2018). Frictional instabilities and carbonation of basalts triggered by injection of pressurized H2O-and CO2-rich fluids. Geophysical research letters, 45(12), 6032-6041.

b) Publications (NON ISI journals)

C. Sinn, P. Giacomel, C.J. Peach, S.J. Hangx, C.J. Spiers. Effect of Plastic Deformation on the Transport Properties of Rocksalt. Mechanical Behavior of Salt IX, 2018. Proceedings (ISBN 978-3-9814108-6-0)

c) Abstracts

P. Giacomel, E. Spagnuolo, M.M. Scuderi, G. Di Toro and C. Collettini (). Frictional properties of basalts in the presence of water: role of fault displacement. EGU General Assembly 2019. Vienna (Austria).

P. Giacomel, E. Spagnuolo, M.M. Scuderi, G. Di Toro, and C. Collettini. *Experimental studies on the frictional instabilities of basalts triggered by the injection of pressurized H2O- and CO2- rich fluids for CO2 storage purposes.* International Symposium on Energy Geotechniques 2018, Lausanne (Switzerland).

P. Giacomel, E. Spagnuolo, M.M. Scuderi, G. Di Toro, and C. Collettini. *Frictional properties of basalts pressurized with H_2O- and CO_2- rich fluids for in-situ CO_2 storage.* Gordon Research Conference on Rock Deformation 2018. Andover (USA).

P. Giacomel, E. Spagnuolo, M. Nazzari, A. Marzoli, N. Youbi, N., Di Toro, G. *Frictional instabilities and mineral carbonation of basalts triggered by injection of pressurized H_2O -and CO_2 -rich fluids.* 11thEURO -conference on Rock Physics and Geomechanics. Ambleside (UK).