Research options available for topic B

Research topics a) and b) offered by every Doctoral Course involved in UNIPhD are frameworks within which every applicant has to present an original research project in collaboration with a Supervisor at the University of Padua.

Potential Supervisors at Unipd have proposed the following detailed research options, which are related to the research topic. They are offered as a guideline and should facilitate your contact with potential Supervisors. Supervisors' e-mail is specified in every research option table. You are welcome to contact them directly.

Note that this research option list is not at all exhaustive and, within the topic you have chosen, you are free to propose a different research project.

Doctoral Course	**GEOSCIENCES**
Macro-area	Physical Sciences and Engineering
Department name	Department of Geosciences
Webpage	*https://www.geoscienze.unipd.it/corsi/scuola-dottorato*
Research topic B	**Interdisciplinary studies of the geology and mechanics of natural and human-induced earthquakes** With an average toll of 50.000 deaths per year over the last two decades, earthquakes are the most dreadful geohazard. However, we know little about earthquake mechanics. Here we propose an interdisciplinary approach which includes field studies of seismogenic faults, laboratory experiments and microanalytical investigations of both natural and experimental fault products to unravel the mechanics of natural and human-induced earthquakes.
Link to the UNIPhD Call (Academic Year 2022/2023)	*https://www.unipd.it/en/uniphd*
Latest Update	*12.01.2022*
#Number of available Research Options	*2* *Scroll down to see all the Research Options*

1 Research Option Description

Doctoral Course	**Geosciences**
Department name	Department of Geosciences
Research topic B	Interdisciplinary studies of the geology and mechanics of natural and human-induced earthquakes
Research option	Experimental studies of fluid-rock interaction and seismic cycle in geothermal fields (Acronym EXPRESSO)
Supervisor	Supervisor: Giulio DI TORO, giulio.ditoro@unipd.it Research group: Antonio Galgaro and Telemaco Tesei UNIPD Marie Violay (Ecole Polytechnique Fédérale de Lausanne, EPFL, CH) Elena Spagnuolo (Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy)
Webpage	http://geo.geoscienze.unipd.it/personal/ditoro-giulio https://scholar.google.it/citations?user=-ui_mNAAAAAJ&hl=it&oi=ao
Context of the research activity and objectives	Geothermal energy is a renewable energy production solution that is now increasingly considered globally, thanks to the continuity of production and substantial ubiquity. However, the injection and extraction of fluids in deep-seated reservoirs for geothermal energy production (e.g., enhanced or medium- to high-enthalpy geothermal systems) can induce seismicity. The safe exploitation of these reservoirs requires a full understanding of the seismic cycle under high temperature and fluid pressure conditions. The main goals of EXPRESSO are the understanding of fluid-rock interaction, fault reactivation, earthquake nucleation, fault healing rates, under hydrothermal conditions (fluid temperatures and pressures up to 450°C and 70 MPa, respectively). The scientific approach will include the exploitation of the most recent and unique rock deformation experimental facilities available in Europe and installed at Padua University, EPFL (CH) and INGV (Italy) plus stateof-the-art microanalytical facilities recently installed at the Padua University. The latter facilities will allow the PhD student to compare the experimental products with those found in nature (e.g., Krafla, Iceland: www.landsvirkjun.com) and to determine the mechanochemical reactions and the deformation mechanisms typical of stimulated geothermal reservoirs induced by extraction and reinjection operations. The results of the project EXPRESSO will contribute to make the geothermal exploitation methods more environmentally sustainable, energetically efficient and more safe by

	proposing the most effective countermeasures to reduce seismic hazard.
Infrastructures	• Rock Mechanics Laboratories at DG-UNIPD, EPFL and INGV • Micro-analytical facilities at DG-UNIPD (OS-TC, FESEM, STEM, XRF, micro-Raman, etc.)
Skills and competencies for the development of the activity	Expertise in experimental rock deformation OR petrophysics OR petrology and geochemistry OR microstructural, mineralogical and geochemical analysis OR numerical modelling in geosciences OR Geothermal energy
Training offer	• Earthquake geology and fault mechanics (UNIPD, 6 credits) • Geothermal reservoir and exploitation (UNIPD, 2 Credits) • Contact mechanics (EPFL, 2 credits) • Experimental Geomechanics (EPFL, 1 credits) • Introduction to earthquake source physics (EPFL, 2 credits) • Transport Phenomena in fluids (EPFL, 2 credits)
Possible Secondments	Academic: EPFL (Switzerland, 9 months, ref. Prof. Marie Violay) and INGV (Italy, 3 months, ref. Ph.D. Elena Spagnuolo) Industrial: Landsvirkjun (Iceland, 3 months, reference Ph.D. Anette Mortensen, https://www.landsvirkjun.com/)

2 Research Option Description

Doctoral Course	**Geosciences**
Department name	Department of Geosciences
Research topic B	Interdisciplinary studies of the geology and mechanics of natural and human-induced earthquakes
Research option	**FL**uid-rock interaction and fracture **S**ealing, **H**ealing, and permeability evolution in geothermal fields (Acronym **FLASH**)
Supervisor	Supervisor: Telemaco TESEI telemaco.tesei@unipd.it Research group: Antonio Galgaro and Giulio Di Toro UNIPD Marie Violay (Ecole Polytechnique Fédérale de Lausanne, EPFL, CH) Elena Spagnuolo (Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy)
Webpage	https://scholar.google.it/citations?user=hpv-x3wAAAAJ&hl=en
Context of the research activity and objectives	Geothermal energy production relies on the availability of specific geologic environments in which the interaction between heat sources, fluids (both natural and human-injected) and wall rocks induces the long-term circulation of hydrothermal fluids. This circulation is mostly governed by the permeability of the host rock, which in turn is ruled either by connected porosity or by fracture/fault systems. Hydrothermal fluids are hot aqueous solutions (with T from about 40°C to 500°C) that strongly interact with the surrounding rocks by dissolution or precipitation of mineral species, depending on the change of properties of the fluid itself (pressure, temperature, pH, Eh, etc.). In particular, precipitated minerals can result in sealing of fractures and faults that may lead (1) to significant changes in the mechanical behavior of the rocks (e.g. higher rock strength or “fault healing”, increase in fluid pressures associated with earthquake nucleation) and (2) to lower energy production and efficiency due to reduced permeability in the geothermal reservoir. The main goals of FLASH are the understanding of fluid-rock interaction under hydrothermal conditions (fluid temperatures and pressures up to 450°C and 70 MPa, respectively). The project will exploit the unique rock deformation facilities installed in the laboratories of Padua University, EPFL (CH) and INGV (Italy) to perform an experimental investigation of the mechanical and permeability properties of reservoir rocks at hydrothermal conditions. State of-the-art microanalytical facilities recently installed at Padua University will allow the PhD student to compare the

	experimental products with those found in nature (e.g., Krafla, Iceland: www.landsvirkjun.com), and to determine the mechanochemical reactions that lead to fracture/fault healing and sealing processes typical of geothermal reservoirs. The results of "FLASH" will contribute to make the geothermal exploitation methods more environmentally sustainable and energetically efficient.
Infrastructures	• Rock Mechanics Laboratories at DG-UNIPD, EPFL and INGV • Micro-analytical facilities at DG-UNIPD (OS-TC, FESEM, STEM, XRF, micro-Raman, etc.)
Skills and competencies for the development of the activity	Expertise in experimental rock deformation OR petrophysics OR petrology and geochemistry OR microstructural, mineralogical and geochemical analysis OR numerical modelling in geosciences OR Geothermal energy
Training offer	• Earthquake geology and fault mechanics (UNIPD, 6 credits) • Geothermal reservoir and exploitation (UNIPD, 2 Credits) • Contact mechanics (EPFL, 2 credits) • Experimental Geomechanics (EPFL, 1 credits) • Introduction to earthquake source physics (EPFL, 2 credits) • Transport Phenomena in fluids (EPFL, 2 credits)
Possible Secondments	Academic: EPFL (Switzerland, 9 months, ref. Prof. Marie Violay) and INGV (Italy, 3 months, ref. Ph.D. Elena Spagnuolo) Industrial: Landsvirkjun (Iceland, 3 months, reference Ph.D. Anette Mortensen, https://www.landsvirkjun.com/)