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PHD POSITION

Geomechanical behavior of fractured geothermal reservoirs through seismic and hydraulic data analysis and numerical modeling

Nos réf. : Ineris - 228231 - ID 2853688

Contract type: PhD research contract in private law

Start date: Octobre 2026

Location: Nancy (France)

Remote work: 100 days per year

Contact for further information: francesca.de-santis@ineris.fr

CONTEXT

Deep geothermal energy is a renewable and non-intermittent energy source, expected to play a major role in the energy transition in France and Europe. However, its development, particularly in naturally fractured reservoirs, raises technical and societal challenges.

Among these, induced seismicity related to fluid injection and production operations is a key issue. While most events are of low magnitude and not felt at the surface, some larger earthquakes may occur, affecting public acceptance of projects and their long-term viability (e.g. Evans et al., 2012; De Santis et al., 2026).

In this context, a thorough understanding of the mechanisms controlling triggering, migration, and intensity of this seismicity is essential to minimize its occurrence and ensure safe and optimized operation of deep geothermal systems.

PHD OBJECTIVES

This PhD aims to improve understanding of the physical processes governing induced seismicity in a naturally fractured deep geothermal reservoir in the Upper Rhine Graben, which has been exploited for over a decade. It relies on an exceptional dataset combining microseismic data, hydraulic data, drilling data, as well as detailed geological and structural information. These datasets have already contributed to analyzing the reservoir's seismic response during both stimulation and operational phases (Baujard et al., 2017; Lengliné et al., 2017; Maurer et al., 2020; Lengliné et al., 2025).

The main scientific challenge of this PhD lies in the integrated analysis of interactions between pore pressure diffusion, stress state variations (poro- and thermo-elasticity), reactivation of pre-existing faults and possible slow and aseismic slip phenomena. The PhD will investigate to what extent observed seismicity can be explained by hydraulic diffusion alone, or whether it results from more complex coupled mechanisms. It will also aim to constrain the spatio-temporal evolution of seismic source parameters (seismic moment, corner frequency, stress drop, etc.) and seismic statistics (b-value, p-value, etc.) in relation to operational conditions, to better characterize reservoir dynamics. The hypotheses developed from data analysis will then be tested using coupled thermo-hydro-mechanical models, incorporating friction laws suitable for both seismic and aseismic slip (e.g., Dublanchet & De Barros, 2021; Gerardi et al., 2024). These models will assess fault stability, explore different operational scenarios and compare numerical results with observations based on field data.

Ultimately, this PhD will aim to estimate the maximum possible earthquake magnitude, considering the reservoir's thermo-hydro-mechanical properties, its structure, and operating conditions. It should also enable the identification of operational indicators and criteria capable of anticipating the occurrence of significant events, to propose recommendations for seismic hazard management at the studied site, and more broadly for deep geothermal projects in fractured environments.

CAREER OPPORTUNITIES

Due to its multidisciplinary nature, at the intersection of seismology, geomechanics, numerical modeling and reservoir engineering, this PhD will provide broad research training. The wide range of approaches employed, combining data analysis, modeling and operational challenges, will allow the candidate to develop skills applicable across multiple fields of geosciences and subsurface engineering.

This PhD will thus open career opportunities in both academia (postdoctoral research, lecturer/researcher positions, public research institutions) and industry, particularly in sectors such as geothermal energy, underground storage, natural and technological risk management, as well as geotechnical and environmental engineering. Experience gained in a partnership between public research and industry will be a strong asset for careers, bridging fundamental research and operational applications.

RÉFERENCES

Baujard, C., Genter, A., Dalmais, E., Maurer, V., Hehn, R., Rosillette, R., Vidal, J., Schmittbuhl, J., 2017. Hydrothermal characterization of wells GRT-1 and GRT-2 in Rittershoffen, France: Implications on the understanding of natural flow systems in the Rhine graben. *Geothermics 65*, 255–268.

De Santis, F., Klein, E., Thoraval, A., Maury, J., 2026. Patterns and controls of induced seismicity in geothermal reservoirs: insights from case studies and implications for hazard assessment and mitigation. *Geothermics 139,* 103665.

Dublanchet, P., De Barros, L., 2021. Dual Seismic Migration Velocities in Seismic Swarms. *Geophysical Research Letters 48*, e2020GL090025.

Evans, K.F., Zappone, A., Kraft, T., Deichmann, N., Moia, F., 2012. A survey of the induced seismic responses to fluid injection in geothermal and CO2 reservoirs in Europe. *Geothermics 41*, 30–54.

Gerardi, G., Dublanchet, P., Jeannin, L., Kazantsev, A., Duboeuf, L., Ramadhan, I., Azis, H., Ganefianto, N., Nugroho, I.A., 2024. Geomechanical modelling of injection-induced seismicity: the case study of the Muara Laboh geothermal plant. *Geophysical Journal International 237*, 818–837.

Lengliné, O., Boubacar, M., Schmittbuhl, J., 2017. Seismicity related to the hydraulic stimulation of GRT1, Rittershoffen, France. *Geophysical Journal Interantional, 208*, 1704–1715.

Lengliné, O., Maurer, V., & Yorillo, A. (2025). Intermittent induced seismicity during the multiyear operation of a geothermal reservoir. *Geophysical Journal International, 242*(1), ggaf160.

Maurer, V., Gaucher, E., Grunberg, M., Koepke, R., Pestourie, R., Cuenot, N., 2020. Seismicity induced during the development of the Rittershoffen geothermal field, France. *Geothermal Energy 8*, 5.

SUPERVISION, LOCATION AND TRAVELS

The PhD will be conducted in collaboration between Ineris, the Geoscience Department of Mines Paris – PSL and Électricité de Strasbourg Géothermie (ESG), who operates the geothermal site studied in the PhD. The PhD is part of the PEPR "Sous-sol bien commun Terre numérique (Digital Earth)" research program.

Supervision:

- Thesis director: Pierre Dublanchet (Mines Paris)
- Co-directors: Francesca De Santis (Ineris) and Farid Laouafa (Ineris)
- Co-advisor: Vincent Maurer (ESG)

The thesis supervisory committee may include other experts from academia and the public research sector.

The PhD student will be affiliated with the Geotechnical and Geophysical Monitoring Unit (AS2G) within the Sites and Territories Division (SIT) at Ineris. This unit, composed of 16 people, is located in Nancy on the ARTEM Campus.

Travels during the PhD include:

- Short missions to Ineris headquarters (Verneuil-en-Halatte, France)
- Regular stays at Mines Paris (Fontainebleau, near Paris, ~20% of total PhD time)
- Missions at ESG (Strasbourg, ~10% of total PhD time)
- Additional travel for conferences in France and internationally.

CANDIDATE PROFILE

The candidate must hold a Master's degree (or equivalent) in geosciences, geophysics, seismology, geomechanics, continuum mechanics, or related fields. A strong background in continuum physics, rock mechanics, and/or seismic signal processing is particularly desirable. Previous experience in seismology (seismic catalog analysis, focal mechanisms, etc.), geomechanics, or numerical modeling is a plus.

Proficiency in scientific programming (Python, MATLAB, or an equivalent language), the ability to work with complex, multidisciplinary datasets, and a strong interest in numerical modeling are required.

The candidate must demonstrate independence, scientific rigor, initiative, and strong writing skills. Teamwork ability is essential.

A strong knowledge of scientific English (reading, writing, and speaking) is essential.

APPLICATION PROCEDURE

The application must be sent to Francesca De Santis (francesca.de-santis@ineris.fr) and must include:

- Detailed CV,
- Transcripts from the last 2 years,
- An example of scientific work (internship report, project report, article, etc.),
- Cover letter explaining motivation for the PhD topic,
- One or two recommendation letters.

Application deadline: May 8, 2026

ADDITIONAL INFORMATION

39-hours work week
49 days of paid leave per year
Gross salary: 2 105 €/month
Duration: 3 years
Flexible working hours
Meal vouchers

ABOUT INERIS

Ineris (French National Institute for Industrial Environment and Risks), with around 500 employees, is a national reference organization under the supervision of the French Ministry of Environment. Its mission is to conduct research and studies to prevent risks posed by economic activities to people and property.

Joining Ineris offers the opportunity to develop skills in research, expertise, and support for public authorities and industry, with access to 30,000 m² of state-of-the-art laboratories and testing facilities.

Our job offer is open to everyone; we want to welcome new talent into an inclusive work environment.