

## PHD POSITION IN GEOMECHANICS

### Numerical Modeling of Coupled Water–Gas–Rock Interactions in Excavation Damaged Zone of Deep Geological Repositories: Insights from the Cigéo Facility

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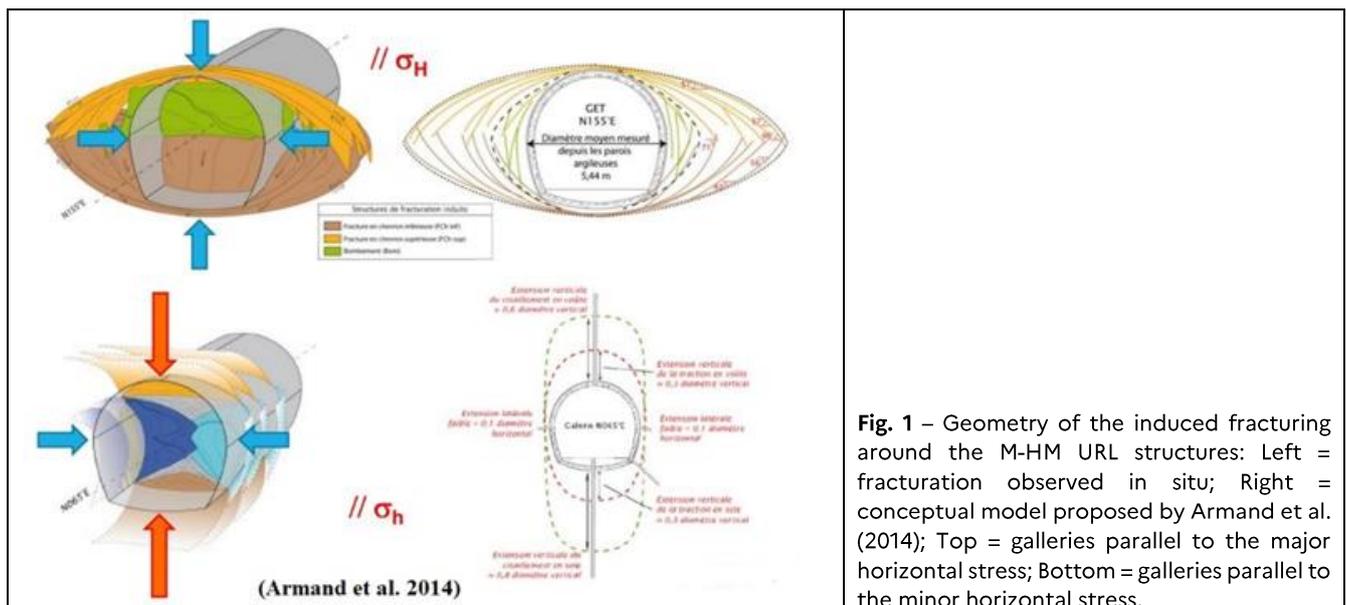
**Type of contract:** PhD Research contract in private law

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#### Scientific context

The long-term safety of deep nuclear waste repositories relies on the stability and low permeability of engineered structures built in claystone formations such as the Callovo–Oxfordian (COx). Excavation induces an Excavation Damaged Zone (EDZ, Fig.1) whose fracture network evolves under mechanical stresses as well as water and gas migration.

For over twenty years, the Meuse/Haute-Marne Underground Research Laboratory (M-HM URL) has provided an exceptional dataset on COx behaviour and EDZ evolution (Armand et al.2014, Souley et al.2026). Yet, conventional continuous numerical models still struggle to reproduce the complex geometry and kinetics of the observed fracture patterns and their effect on the near-field. Emerging discontinuous and hybrid modelling approaches offer promising avenues for more realistic predictions of EDZ development, while also introducing new scientific challenges (Camusso et al.2022, Thoraval 2023, Thoraval et al. 2026).



**Fig. 1** – Geometry of the induced fracturing around the M-HM URL structures: Left = fracturation observed in situ; Right = conceptual model proposed by Armand et al. (2014); Top = galleries parallel to the major horizontal stress; Bottom = galleries parallel to the minor horizontal stress.

## Dissertation topic

The purpose of this thesis is to refine and consolidate the discontinuous and hybrid modeling methodologies applied to Cigéo structures recently explored by Thoraval et al. (2026) with the goal to:

- Characterize the formation, evolution, and impact of fractures in underground storage structures.
- Quantify the influence of hydraulic, gaseous, and mechanical loads on fracture initiation and propagation.
- Evaluate the resulting effects of fracturation on the overall assessment and performance of Cigéo's closure structures and underground storage systems.

## What you will do in practice

- **Field data analysis:** You will work with a unique database compiled from more than two decades of in-situ monitoring (pressure, deformation, fracturing, etc.) and laboratory tests to characterise the formation and evolution of the EDZ around the Cigéo facilities.
- **2D/3D numerical modelling (DEM, FEM):** You will develop and apply innovative discontinuous or hybrid geomechanical models initiated in the exploratory work of Thoraval et al. (2026) to simulate fracture development, its long-term evolution, and the effects of hydraulic, gaseous, and mechanical loads, including the resulting water–gas–rock interactions.
- **An approach built on gradually increasing the complexity of the matrix and fracture behavior:** linear → nonlinear, anisotropy, time-dependent effects, hydromechanical coupling in saturated single-phase conditions (water, gas).
- **Validation based on comparison with field measurements and with the numerous predictions of continuous CO<sub>x</sub> models described in the literature:** You will compare your numerical results with field observations, propose additional interpretations of the measurements when needed, and contribute to refining numerical models based on recent scientific advances and the interpretation of underlying physical mechanisms.
- **Safety assessment of structures:** You will analyze the consequences of the fracturing evolution on the short-, medium-, and long-term stability and performance of Cigéo's closure structures and related underground storage components.
- **Collaboration and communication:** You will collaborate with recognized specialists (Ineris, University of Lorraine, Andra), present your findings in meetings, seminars, and conferences, and take an active role in the scientific life of a dynamic international research team.

## Why is this topic so exciting?

- **A real-world challenge:** Your work will contribute directly to environmental safety and responsible management of the highest-hazardous radioactive waste.
- **A unique Rock Mechanics URL:** You will have access to a world-class underground research laboratory with exceptional data and rare experimental conditions.
- **A scientific and human adventure:** You will join a dynamic, multidisciplinary and international team where collaboration, curiosity and innovation drive everyday progress.
- **A wide range of rewarding skills:** Your work will enable you to further develop skills in modeling, data analysis, interpretation of experiments, scientific communication — you will develop expertise that is in high demand across a wide range of industries.

- **A wide range of career opportunities:** At the end of your PhD, you will be able to pursue a career in industry, public research, or higher education, both in France and internationally.

### For whom?

- Master's degree (M2) or engineering diploma in geosciences, civil engineering, mechanics, physics, or related fields.
- Curious and motivated by major environmental and industrial challenges.
- A desire to understand, model, challenge results, and see the real-world impact of your work.

### Project advantages

- **High-quality supervision** provided by a joint team from Ineris, the University of Lorraine, and Andra.
- **Attractive remuneration**, approximately 2,200 € per month.
- **Mobility and networking opportunities**, including travel within France and internationally as well as participation in scientific conferences.

### Application profile

- **Application deadline: March 20, 2026**
- **Required documents:**  
Curriculum vitae – Copies of the certificates for each university degree and the corresponding transcripts – Motivation letter – Any recommendation from your professors and/or supervisors.
- **Eligibility:**  
All intra-EU candidates – Non-EU candidates who already hold student status in France – Holders of a Master's degree or equivalent – Skill in French and/or English: written and spoken.

### Contact

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### Reference

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**This position is open to people with handicaps.**