China Scholarship Council / Université de Lyon
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Call for Thesis subjects: 2024

RESEARCH SUBJECT TITLE:

Modelling the impact of mineral composition on the hydromechanical properties of rocks: from hydrothermal alteration to the large-scale behaviour of reservoirs

Name of the laboratory: Tribology and Systems Dynamics Laboratory (LTDS).
Website: http://ltds.ec-lyon.fr

Name of the research team: Geomaterials and Sustainable Construction (GCD)
Website: http://ltds.ec-lyon.fr -> "Géomatériaux et Construction Durable"

Name of the supervisor: Antonin FABBRI (DR, HDR, supervisor)
Benoît PARDOEN (CR, co-supervisor)

University / Institution: University of Lyon,
French National School of State Public Works (ENTPE).

E-mail addresses: benoit.pardoen@entpe.fr

Doctoral School: Mechanics, energetics, civil engineering, acoustics (MEGA)

Lab Language: English and French

Minimum language level required:

- English : Good / Fluent (in accordance to the doctoral school admission rules)
- French : -
- Other : -

Expected duration of the thesis: 48 months

Keywords : rock alteration, micromechanical properties of rocks, multi-physical and multi-scale modelling.

Abstract:

CONTEXT

The analysis of the socio-economic potentials and challenges related to the **exploitation and use of the soil and subsoil** in the demographic (constructible and exploitable surfaces, transport, etc.) and energy (geothermal, geological storage, etc.) current context is crucial. The current context of **energy transition** aims in particular to gradually move from the use of limited and polluting energies (fossil fuels, radioactive wastes, greenhouse gases, etc.) to renewable and environmentally friendly energies. This fundamental environmental transition, towards a world with "carbon-free energy", requires an increased knowledge of the processes of formation and exploitation of the mineral and energy resources of the subsoil. This knowledge is necessary in order to better consider their exploration and exploitation. It is therefore important to assess the **potential of the underground space as an energy resource** (high temperature geothermal energy, hydrocarbons, gas, etc.) and also as a storage and confinement space (energy carriers, CO2, nuclear waste, etc.). Among the underground energy resources, the production of electricity by **deep geothermal energy at high enthalpy** is a sector which consists of one of the strategic pillars of the energy transition (French and international), with exploitation projects in various regions (in France: Rhenish ditch, Alsace, Massif Central, Massif Armoricain, Overseas, regions of recent volcanism). The major challenges of high-enthalpy geothermal exploitation lie in the **safety and durability of underground exploitation structures** (e.g. deep boreholes), in knowledge of geothermal systems (Pirajno, 2009), as well as in the **quality hydrothermal fluid reservoirs** (i.e., fluid storage and production capacity).

A **reservoir rock** is a permeable rock formation (porous or fractured) whose porosity (pore or fracture) allows the accumulation of fluids. Concerning the geothermal exploitation of high enthalpy hydro-geothermal reservoirs (Violay, 2010), it consists in a reserve of hydrothermal fluids associated with geothermal systems. These natural systems, dominated by fluid flows within reservoir rocks, are vectors of thermal energy transfer at great depth, inside the earth's crust. Thus, the **quality of reservoirs is conditioned by the hydraulic characteristics of the host rocks**, such as porosity and permeability, which are themselves conditioned by their mechanical behaviour (deformation of the pore space, degree of damage or fracturing, etc.). These large-scale characteristics (macroscopic geological scale and reservoirs scale) are conditioned by the structure and rock mineral composition on a small scale (scale of mineral grains, of their proportion and arrangements, of pores/fractures, of flows, etc.) (Cosenza et al., 2015; Pardoen et al., 2020). However, **the impact of mineral composition on the hydromechanical properties of rocks**, at different scales, is a topic of current interest in geomechanics and earth sciences. It is particularly well known that clay minerals give clayey soils/rocks (composed of fine clay particles or of a clay matrix) low hydraulic permeability and mechanical rigidity (low stiffness). These properties cause a reduction in fluid circulation capacities and an increase in the deformability of rocks. This can alter the reservoir function of rocks, or even the formation and exploitation of deep geothermal deposits. Moreover, in geothermal environments, an evolution of mineral composition and porosity is often observed. This process results from the alteration of rocks, caused in particular by underground fluid-rock interactions (Rigault et al., 2010). However, despite the interest it represents, **the impact of clay minerals, and of their evolution, on the quality of hydrothermal fluid reservoirs** (and deep geothermal deposits) **remains little known, and therefore needs to be studied**.

OBJECTIVES

The objective of the proposed study is to:
(i) take into account the **(clayey) rock mineral composition in the determination of the hydromechanical properties of rocks** (porosity, deformability, strength, permeability),
(ii) model the **evolution of the clay content and** deduce the **modifications of the properties** (evolution linked to the alteration of the rocks),
(iii) predict the impact on **large-scale behaviour**, on the **qualities of the reservoirs**.

The **research objective** will therefore be to develop a rheological model and a modelling (theoretical and numerical) of the multi-physical behaviour of thermo-hydromechanical (THM) processes within rocks (porous/fractured) of a geothermal system. Macroscopic approaches will be developed based on the behaviour at the scale of material constituents. The work undertaken will make it possible to consider the influence of microstructural mineralogical characteristics on the rocky behaviour of reservoirs on a larger scale.

The research developed will combine theoretical and numerical modelling (continuous finite element approach). It will be based on theoretical and numerical work (previous or in progress) carried out within the LTDS laboratory by the supervisors on the development of rheological models and the study of the multi-physical behaviour of rocks and soils (Pardoen et al. (2016); Pardoen et al. (2020); Fabbri and Fen-Chong (2013); Bui et al. (2017); Li et al. (2022); Sun et al. (2021))

APPLICATION

Applications should be submitted by emailing a CV, academic grades (detail of marks), scientific/academic references, and recommendation letter to the supervisor at benoit.pardoen@entpe.fr. Any additional document relevant for the application can also be transmitted, especially for international applications.

References:

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Sun, Y., Wong, H., Pardoen, B., Deleruyelle, F., Dufour, N., Branque, D., Leo, C. (2021). Analytical study of post-closure behaviour of a deep spherical cavity in a dilatant viscoplastic rock mass. Computers and Geotechnics. 139(3):104419.