Ph.D. position in clay geomechanics and geochemistry
University of Orléans (Orléans, France) - BRGM

We are opening a Ph.D. position at the Institute of Earth Sciences of Orléans (ISTO), University of Orléans, and BRGM, on the topic: "***Influence of temperature on swelling pressure of bentonites: from mechanical tests to atomic scale model***".

Bentonites, composed mainly of smectite, a swelling clay mineral, are geological materials used as natural barriers for the storage and containment of polluted systems, radioactive waste, etc. Beyond its anthropized use, smectite is also a mineral that occurs naturally in soils.

Whatever their use, the mechanical and hydraulic properties of bentonites are likely to be significantly modified under the effect of a thermal gradient (radioactive waste, global warming), which could potentially reduce their performance. The aim of this Ph.D. thesis project is to investigate this issue by coupling laboratory mechanical tests (oedometer tests at variable temperatures, from 25 to 150°C) with clay hydration modelling based on in situ acquisition of X-ray diffusion (WAXS).

Hydration mechanical tests in oedometers will be carried out on homo-ionized materials (Na+ and Ca2+), enabling the evolution of swelling pressure to be followed over time, coupled with real-time in situ WAXS acquisitions allowing the proportion of water layers (0, 1, 2 and 3 W, following Ferrage (2016)), as well as texture anisotropy, to be determined and related to macroscopic swelling pressure. Tests will be carried out on (1) model systems consisting solely of smectite and (2) a system made up of a mixture of smectite with quartz (non-swelling phase), to take into account the contribution of the rigid skeleton, contained in natural bentonites, on the impact of mechanical properties. Finally, experimentally-derived macroscopic properties (swelling pressure, hydration states, texture anisotropy) will be modelled and interpreted using different theoretical approaches (for example DLVO or granular mesoscale model, e.g. Asadi et al. (2022), Liu (2013)).

This project builds on the long-established collaboration between BRGM, involved in research concerning the mechanical and water properties of clays in the context of nuclear waste storage, and ISTO, a cutting-edge laboratory for high- pressure and temperature experiments. This project is an extension of the Ph.D. theses of Luc Massat (Massat et al., 2016) and Roy Chaaya (Chaaya et al., 2023).

The project will be supervised by Hugues Raimbourg (Professor, ISTO), Benjamin Langérome (research engineer, ISTO) and Stéphane Gaboreau (BRGM). The starting date is planned in the **early October 2025**. The position is funded for **3 years**. The project will be hosted in the **Institute of Earth Sciences of Orléans** (https://www.isto-orleans.fr/en/home/) at the University of Orléans (http://www.univ-orleans.fr/en) and at **BRGM** (French geological survey; https://www.brgm.fr/fr). This project is integrated in the Magmas-Geodynamics research group of ISTO whose main focuses include the understanding of the mechanical behaviour of

the lithosphere and the interplay between mineral reactions and deformation. This project is also part of the ANCHOR work package of the European project EURAD II (https://www.ejp-eurad.eu/) conducted at BRGM. Its main focus is to enhance knowledge of the confining barrier used in radioactive waste storage.

We are looking for a highly motivated student with a strong interest in clay geochemistry and geomechanics. Experience with high-pressure experiments, X-ray diffraction, thermodynamics and mechanics will be a plus. The applicant should hold a Master degree (or equivalent) in Earth Sciences.

Enquiries regarding the specifics of the project should be directed to Hugues Raimbourg: hugues.raimbourg@univ-orleans.fr.

The application should include a full CV, transcripts of academic degrees, a statement of research interests and the contact information of two potential referees. The application should be submitted to hugues.raimbourg@univ-orleans.fr as a single pdf. Applications will be possible until the **4th of April 2025**.

References

Asadi, F., Zhu, H.-X., Vandamme, M., Roux, J.-N. and Brochard, L. (2022) A meso-scale model of clay matrix: the role of hydration transitions in geomechanical behavior. Soft Matter 18, 7931-7948.

Chaaya, R., Gaboreau, S., Milet, F., Maubec, N., Tremosa, J., Raimbourg, H. and Ferrage, E. (2023) In-operando X-ray scattering characterization of smectite swelling experiments. Applied Clay Science 245, 107124.

Liu, L. (2013) Prediction of swelling pressures of different types of bentonite in dilute solutions. Coll. Surf. A 434, 303-318.

Massat, L., Cuisinier, O., Bihannic, I., Claret, F., Pelletier, M., Masrou, F. and Gaboreau, S. (2016) Swelling pressure development and inter-aggregate porosity evolution upon hydration of a compacted swelling clay. Applied Clay Science 125-125, 197-210.