Ph.D. project on "Creep of clays:
Experiments on thin clay films and their molecular modeling"

The mechanical properties of clay-based materials are critical in a variety of applications, such as nuclear waste storage, hydraulic fracturing, or the assessment of slope stability. In particular, the creep behavior of those materials (i.e., their propensity to deform over time when mechanically loaded) is of interest. Indeed, since the time scale of nuclear waste storage in underground clay rocks is extremely long (~ 100,000 years), creep will impact the long-term stress distribution in the rocks. Also, for what concerns hydraulic fracturing, creep can lead to a delayed closure of the created fractures and hence mitigate the expected permeability enhancement. In geotechnical engineering, creep can lead to delayed failures of soils and hence plays a role in landslides. In this Ph.D. project, we aim at identifying the physical origin of clay creep, through a combination of original experiments on clay systems and of molecular simulations (both aspects are equally important).

We have demonstrated in the framework of the Ph.D. thesis of B. Carrier the relevance of experimentally studying thin (i.e., thickness around 50µm) clay films[1] as model of realistic clay systems. The objective of the PhD is to observe experimentally the films while they creep on one hand and on the other hand to model the systems using coarse-grained simulations.

The experimental studies on the films upon creeping will be performed using a variety of techniques of complementary scales: 1) environmental scanning electron microscopy, 2) X-ray radiography and transmission X-ray microscopy, 3) small angle X-ray scattering, 4) nuclear magnetic resonance. The combination of these observations will yield information on rearrangements of the micro/meso-structure and/or porosity of the films concomitant to creep.

In terms of molecular modeling, the work will be based on coarse-grained simulations of assemblies of flat but flexible clay particles (see Figure) developed recently at Laboratoire Navier. First, the modeling will be validated by comparing numerical predictions with experimental data obtained by B. Carrier on clay films in terms of humidity-induced swellings and variations of stiffness. Then, the molecular model will be used to perform hypothesis testing on the potential physical origin of creep. To do so, we will implement various physical ingredients in the model (e.g., opportunity for neighboring particles to slide over each other) and compare the numerical predictions with the outcomes of the experimental study on the creep of clay films.

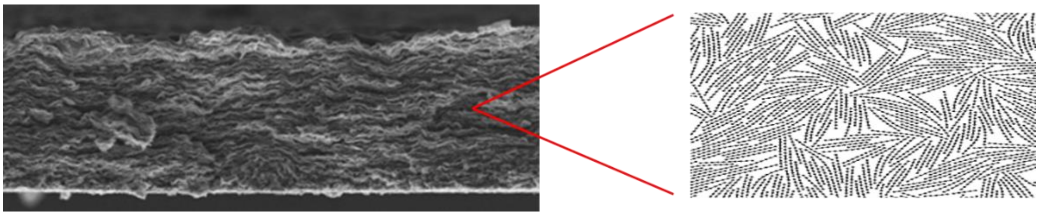

Figure: (left) Example of clay film of thickness around 50µm and (right) example of coarse-grained molecular model.

The candidate must have a solid background in mechanics, materials science, physics, or civil engineering. He/She will also have a strong taste for both experiments and numerical modeling.

Advisors: Matthieu Vandamme (Laboratoire Navier, Ecole des Ponts ParisTech), Laurent Michot (Phenix, Sorbonne Université), Timm Weitkamp (Synchrotron Soleil)

Duration: 3 years, starting in Fall 2018

Location: Laboratoire Navier, Ecole des Ponts ParisTech, in Champs-sur-Marne, just outside Paris

Salary: Net salary of about 1600€ per month

To apply: By **1 April 2018**, please send CV, transcripts and motivation letter to matthieu.vandamme@enpc.fr

[1] B. Carrier, M. Vandamme, R. J.-M. Pellenq, M. Bornert, E. Ferrage, F. Hubert, and H. Van Damme, Langmuir **32**, 1370 (2016).