PhD project

Seismic wave propagation in multi-scale fractured media

Tectonic processes and the industrial exploitation of the subsurface induce brittle deformations in the earth crust, leading to fractures at all scales. These fractures are organized in networks which are basically characterized by their density, connectivity, and distribution of aperture, length and orientation. Determining these parameters are essential for predicting the hydrogeological behavior of reservoirs or understanding the fatigue of soils and engineering structures. However, direct measurements of fracture parameters are rarely available. Apart from outcrops, cores and borehole images, fractured rocks are seen in an effective way through mechanical properties derived from mechanical tests or seismic wave data. The aim of the PhD project is to improve our understanding of the interaction between seismic waves and fractures.

Geological observations have evidenced that a power law is appropriate to describe the density of a fracture set as a function of fracture size (e.g., Bonnet et al., 2001). Nevertheless, for either theoretical or computational reasons, studies on seismic wave propagation in fractured media have been restricted to a short range of sizes so far. To overcome this limitation, the present project will build on recent progresses in non-periodic homogenization (e.g., Capdeville et al, 2010; Guillot et al, 2010; Cupillard & Capdeville, 2018; Capdeville et al, 2020) to compute effective properties of fractures following realistic power law distributions. The numerical methodology will be tested and validated against laboratory experiments on core samples.

Advisors: Paul Cupillard & Dragan Grgic (GeoRessources)

Starting date: May 2025

Location: Nancy (France), a UNESCO World Heritage city with a vibrant student life and a rich cultural agenda, only 90 minutes away from Paris, Luxembourg and Strasbourg.

Working environment: The successful candidate will work in the RING Team, a pluridisciplinary and diverse group of 12-15 researchers and graduate students working at the interface of geoscience, computer science and applied mathematics. The team is part of École Nationale Supérieure de Géologie in the GeoRessources laboratory, a research lab of Université de Lorraine and CNRS. The research team is driven by passion for developing computer-based methods and theories for geological and geophysical modeling, serving the geoscience community to address scientific and natural resource management challenges.

Requirements: The candidate should hold a MSc in quantitative Earth Sciences, Geophysics, Physics, Geomechanics, Applied Mathematics or Computer Science. He/she is passionate about science and has solid scientific writing skills. An experience in computer programming and a strong command of English language are required. French language is preferable, but not necessary.

How to apply:
Application files must be sent to jobs@ring-team.org **before January 31, 2025,** and must include:

- A cover letter,
- A CV, including contact information for two or more referees,
- A research outcome (Master thesis or paper) written by the candidate,
- An official transcript of grades.

References:

Bonnet, E., O. Bour, N. E. Odling, P. Davy, I. Main, P. Cowie, and B. Berkowitz (2001). Scaling of fracture systems in geologic media, *Rev. Geophys.* 39, 347–383.

Capdeville, Y., L. Guillot, and J. Marigo (2010). 2-D non-periodic homogenization to upscale elastic media for P-SV waves. *Geophys. J. Int.* 182, 903–922.

Capdeville, Y., P. Cupillard, and S. Singh (2020). An introduction to the two-scale homogenization method for seismology, *Adv. Geophys.* 61, 217–306.

Cupillard, P. and Y. Capdeville (2018). Non-periodic homogenization of 3-D elastic media for the seismic wave equation. *Geophys. J. Int.* 213(2), 983–1001.

Guillot, L., Y. Capdeville, and J. Marigo (2010). 2-D non-periodic homogenization of the elastic wave equation: SH case. *Geophys. J. Int.* 182, 1438–1454.