e2s UPPA energy environment solutions	**DOCTORAL POSITION**	UNIVERSITÉ DE PAU ET DES PAYS DE L'ADOUR

From : **September 1st 2018 to September 1st 2021**

Title:

Modeling of conducting poro-elastic media using advanced numerical methods

Thesis abstract:

A seismic wave propagating in a porous media generates electromagnetic (EM) wavefields through the so-called seismoelectric conversion. The EM contribution can then be divided into two different categories 1) a co-seismic transient electric field accompanying the seismic wave, 2) an electromagnetic wave generated by the conversion of seismic into EM energies at the interface separating two different porous media. The first EM wave follows the seismic and does not carry that much more information compared to the seismic whereas the depth-converted EM waves have potentially huge application in near-surface Geophysics since, for example, a water-oil contact would generate an EM seismoelectric conversion where the seismic field could be poorly sensitive to such an interface. The quantitative understanding of the conversion at interfaces is still poorly known and has only been seldom observed in the field and in a few laboratory experiments.

The objective of the Phd thesis is the development of numerical methods that are adapted to poro-elastic media in the perspective of a coupling with electromagnetic waves. This task requires an important amount of work which will represent a PhD thesis including both mathematical analysis and top-flight computer developments. We have identified some important issues to be addressed in the framework of this part of the project. First, the implementation of the solution of wave problems in porous media is a key step of the project which should last one year, including the validation of the numerical solution thanks to Gar6more (Diaz and Ezziani, 2010a; Diaz and Ezziani, 2010b), which provides analytical solutions in porous media. This is a considerable work of development that has to be carried out in the environment of our software package Hou10ni (https://team.inria.fr/magique3d/software/hou10ni/), which already allows for the solution of elastic and acoustic wave problems in heterogeneous media, using Discontinuous Galerkin methods. We will use in particular the Biot's equations and for that purpose, the PhD student will draw upon the expertise of (Ezziani, 2005). The ultimate validation of the solver will be based on comparisons with published results, like for instance Morency and Tromp (2008). In particular, this work will provide interesting performance assessments by comparing DG-element with Spectral-element simulations. Once this first software brick is carried out, the question will be how to tackle the tricky problem of ensuring stable numerical approximations of wavefields with wavelengths that vary from the nanometer to the meter. One idea could be to begin with a quasi-static representation of the electric field in order to focus on the full discretization of the mechanical wavefield. This has been previously done in Imperial (2012) and following this former experience could be a good way to quickly begin with the electro-mechanical coupling, using what was formerly done during the first year. Regarding the quasi-static version of Maxwell's equations, we intend to use the methodology proposed in Montjoie (https://www.math.u-bordeaux.fr/~durufle/montjoie/) and to extend it to Hou10ni in view of performing the coupling with the Biot's equations. In the same time, we will work on a way of achieving the coupling of the full equations. One idea consists in developing a multi-level method as it was suggesting in Glowinski et al. (2005) for elliptic problems. Recent results in Abdulle and Huber (2016) suggest that it is possible to develop a finite element approximation for electro-seismic coupling. The idea is to use a multiscale method that approximates the homogenized solution by using numerical upscaling which couples macro and micro finite elements. To the best of our knowledge, this approach has never been applied to the propagation of waves in conducting poro-elastic media.

References

Abdulle, A. and Huber, M.E., *Finite Element Heterogeneous Multiscale Method for Nonlinear Monotone Parabolic Homogenization Problems*, Esaim-Mathematical Modelling And Numerical Analysis-ModélisationMathématique et Analyse Numérique, vol. 50, num. 6, p. 1659-1697, 2016.

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Ezziani, A., M*odélisation mathématique et numérique de la propagation d'ondes dans les milieux viscoélastiques et poroélastiques*, PhD thesis, Université Paris Dauphine, 2005.

Glowinski, R., He, J., Lozinski, A., Rappaz, J. and Wagner, J., F*inite element approximation of multi-scale elliptic problems using patches of elements*, Numerische Mathematik, Volume 101, Issue 4, pp 663–687, 2005.

Imperial, S., *Modélisation mathématique et numérique de capteurs piézoélectriques*, Ph.D thesis, Université Paris Dauphine, 2012.

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Key words:
Wave propagation, porous media, seismoelectric, electromagnetic, numerical modeling, Discontinuous Galerkin, multiscale method.

Funding:
E2S scientific challenges project from the university of "Pau et des Pays de l'Adour" UPPA

Working conditions

Hosting laboratory:
Inria Team Project Magique 3D

Localisation address:
Université de Pau et des Pays de l'Adour, campus of Pau, Pyrénées-Atlantiques, France

Laboratory expertise

The Inria project-team Magique 3D has recognized expertise in mathematical modeling of sub-surface geophysical phenomena and in the design and the analysis of numerical methods for their simulations.

Created to apply recent advances in three-dimensional scientific computing to different areas in geophysics, and particular seismic wave propagation, Magique-3D is a joint project-team between Inria and the Department of Applied Mathematics (LMA) of the University of Pau, in partnership with CNRS.

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The mission of Magique-3D is to develop and validate efficient solution methodologies for solving complex three-dimensional geophysical problems, with a particular emphasis on problems arising in seismic imaging, in response to the local industrial and community needs.

Thesis Directors: Hélène Barucq (Inria-LMAP) and Julien Diaz (Inria-LMAP)
Scientific team: **MAGIQUE-3D**

Starting Date: September 1st 2018
Duration: 3 years

Gross salary: 1 870 € / month (which includes extra gratification for teaching duties – 32h per year)

Mission - Main activities:

Scientific framework

The proposed PhD is part of a project called « CHaracterIzation of Conducting Poro-elastic media using Experimental and advanced numericAl methods" (CHICkPEA) led by H. Barucq (LMAP-Inria), funded by E2S-UPPA from 2018 to 2021. CHICkPEA, one of the two selected propositions within the "New Challenges E2S-UPPA", is a transdisciplinary Mathematics/Geophysics project. 2 PhD and 1 Post-Doctorate have been funded for the CHICKPEA project: PhD1 on the experimental/modeling side and PhD2 (the present proposition)& the Post-Doc on the numerical/programming side. PhD1, PhD2 and Post-Doc will all start in 2018.

Purpose(s)

The goal of CHICkPEA is to improve the accuracy of the images by developing new models and numerical methods for the simulation of elastic and electromagnetic wave propagation in porous media. The numerical model (developed by PhD2 and Post-Doc) will be confronted to laboratory experiments carried out in saturated sand where propagating mechanical and electromagnetic waves will be precisely monitored (PhD1).

Expected results

The expected outcomes of the project are : one experimental protocol for understanding electro-mechanical wave propagation and physical properties in porous rocks, one piece of software for the simulation of elastic and electromagnetic waves, one inverse problem solver able for characterizing conducting porous media from the knowledge of the diffracted seismic or electromagnetic fields. The targeted applications are geothermal exploitation, CO2 storage and oil exploration.

Research collaborations

CHICkPEA is a collaborative project between the LMAP-Inria (Laboratory of Applied Mathematics) and LFCR (laboratory of complex fluids and reservoir), between applied mathematicians and geophysicists. The collaboration between both groups and in particular between the 2 PhD students and the Post-Doctorate will a key of the success of this project. The two labs are located in the same building in the Pau university campus.

Applicant's profile:

The candidate should be interested in the design and analysis of numerical methods and should also have a strong predilection for their implementation on computer.

Particulars skills are sought in finite element methods, elastodynamic modeling, poro-elastic modeling, electromagnetism, code development (Fortran or C++).

The ideal candidate has a master degree in Applied Mathematics. He/She is rigorous and highly motivated. The candidate must have a good English level and the capacity to work autonomously.

Application - Evaluation criteria:

Application file assessment: Selection committee

Candidates will first be selected based on their application file.

Those selected after this first step, will then be interviewed.

Application files will be evaluated based on the following criteria:

- Grades and ranking during your Master degree, steadiness in your academic background
- English language proficiency
- Candidate's ability to present her/his work and results

Work experience similar to an internship in a laboratory – or likewise; previously achieved research work (reports, publications).

Application will include: *(in a single pdf file)*

- CV
- Cover letter
- Master degree grade transcripts and ranking
- Reference letter
- Contact details of at least two people, from you work environment, who can be contacted for further reference

Application must be send to the following email address with the title “Doctoral application”: **helene.barucq@inria.fr**

For more details, please visit our websites: **http://e2s-uppa.eu/en/index.html**

Application deadline:

1st May 2018