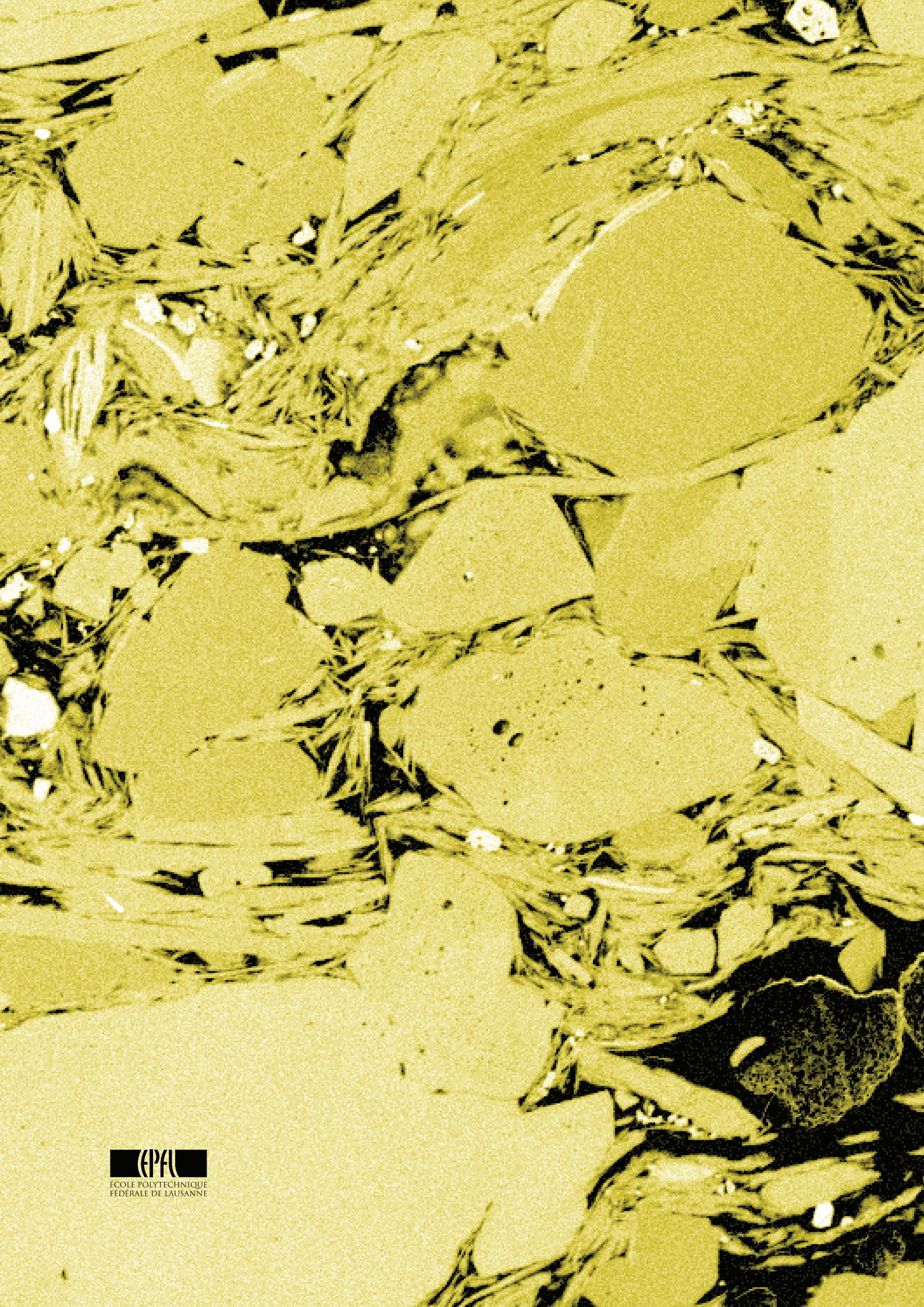


**Laboratory for  
Soil Mechanics**  
Chair “Gaz Naturel”  
Petrosvibri





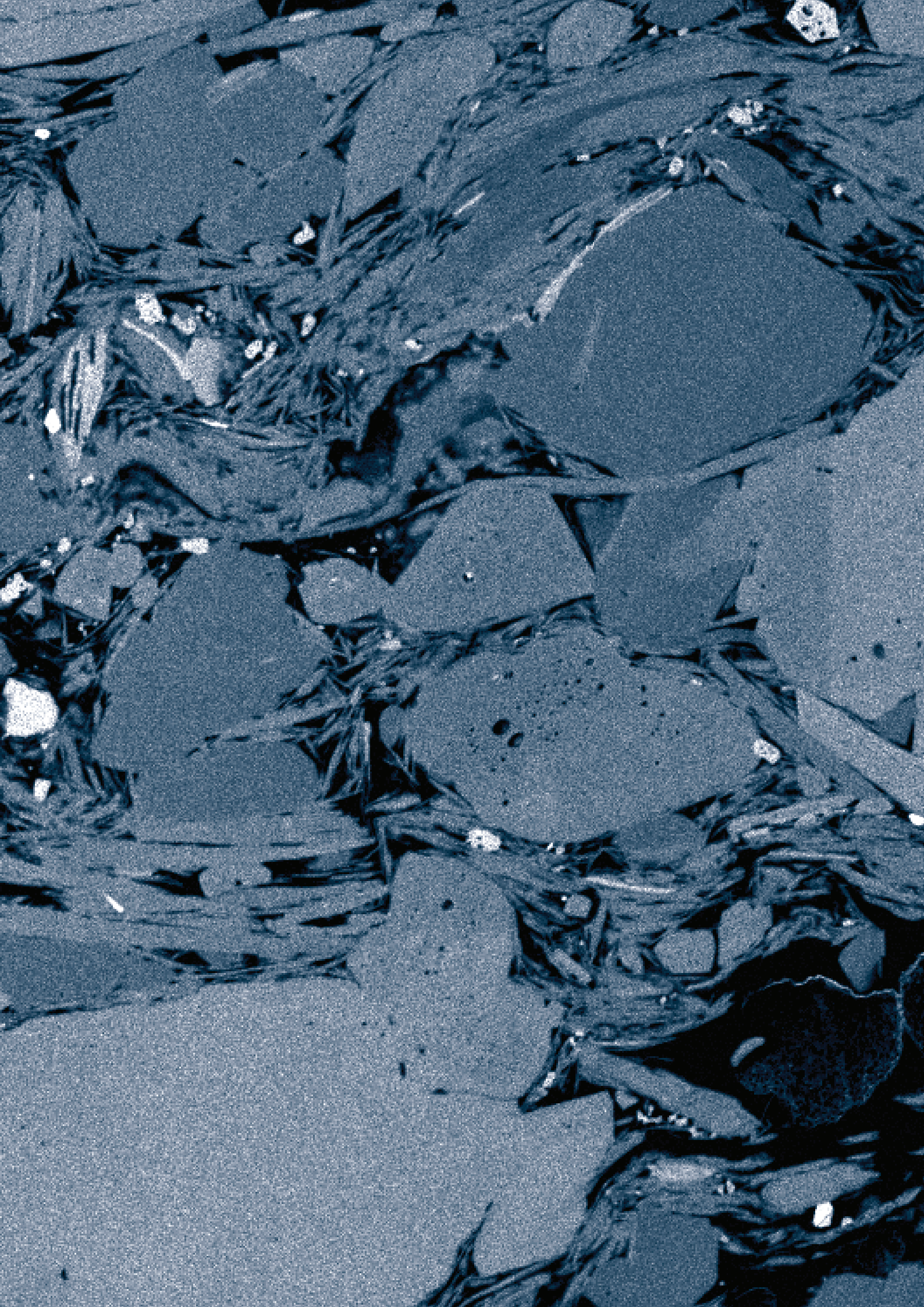
## Summary

---

**In the framework of the energy transition and reduction of the greenhouse gases emission, carbon capture storage (CCS) in underground formations gained significant visibility at the international level in the past years. For this reason, this negative emission technology is at the core of the research activity of the Chair “Gaz Naturel” – Petrosvibri at the EPFL.**

**A significant step forward towards the implementation of this technology has been made in 2018 with ELEGANCY project. 2018 has been also the first year of the WP1 of the SCCER-SoE with Prof. Laloui as leader. Scientific research in the package shows a good maturity. Significant effort has been also made in cooperation with Swiss Federal Office of Energy to start the interaction with the industry sector in order to plan the transition from the R&D level to operational level.**

**In 2018, the research activities carried out by the Chair have been definitely extended to a new domain related to induced seismicity. This topic is of great importance for all the engineering applications that foresee the injection of fluids underground. Moreover, the Chair is also planning to expand its expertise in the framework of rock-fluid interaction.**



2

**new people joined the Chair**

5

**ongoing research projects**

3

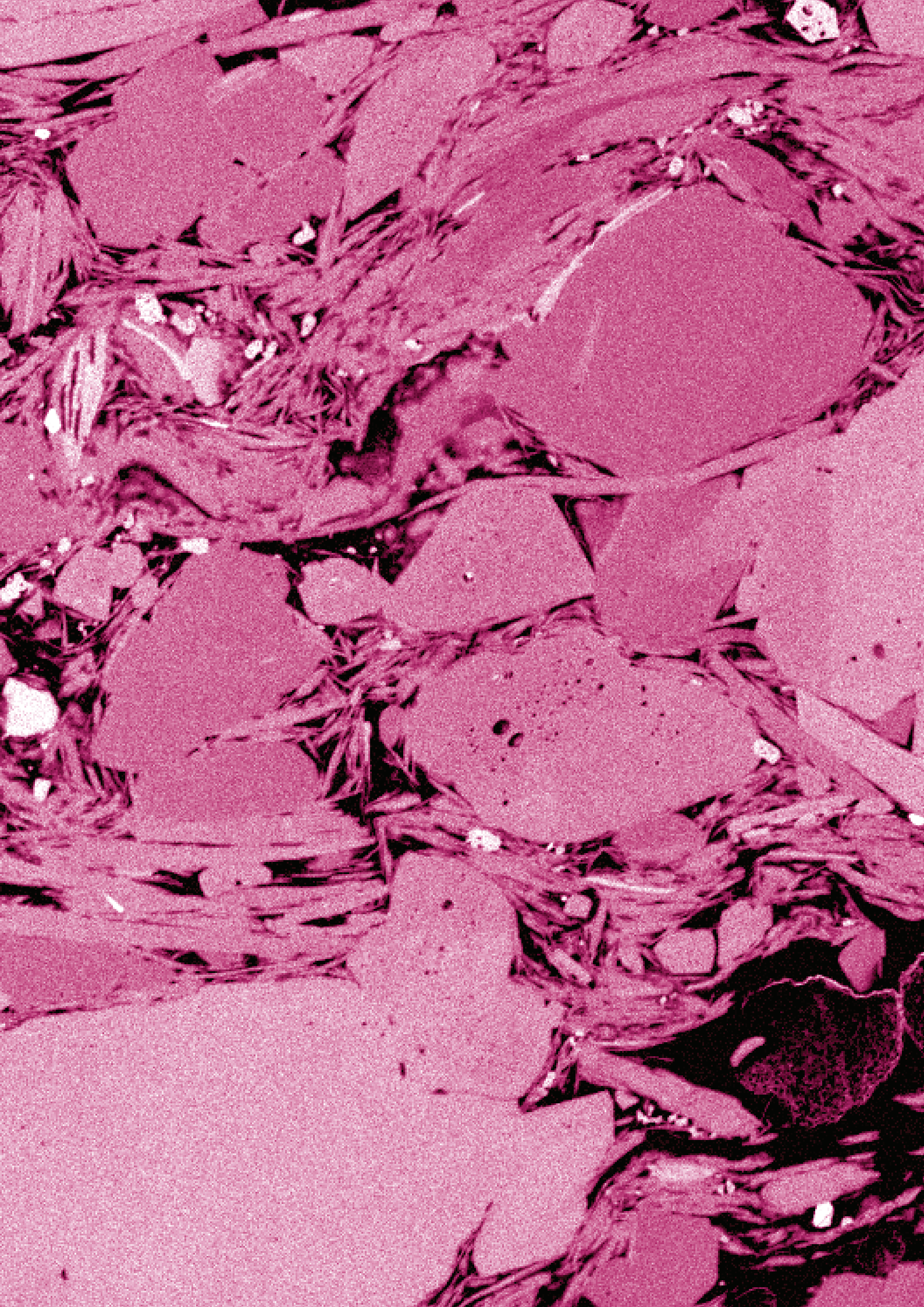
**organized scientific events**

15

**scientific talks delivered in international conferences**

8

**research partners**

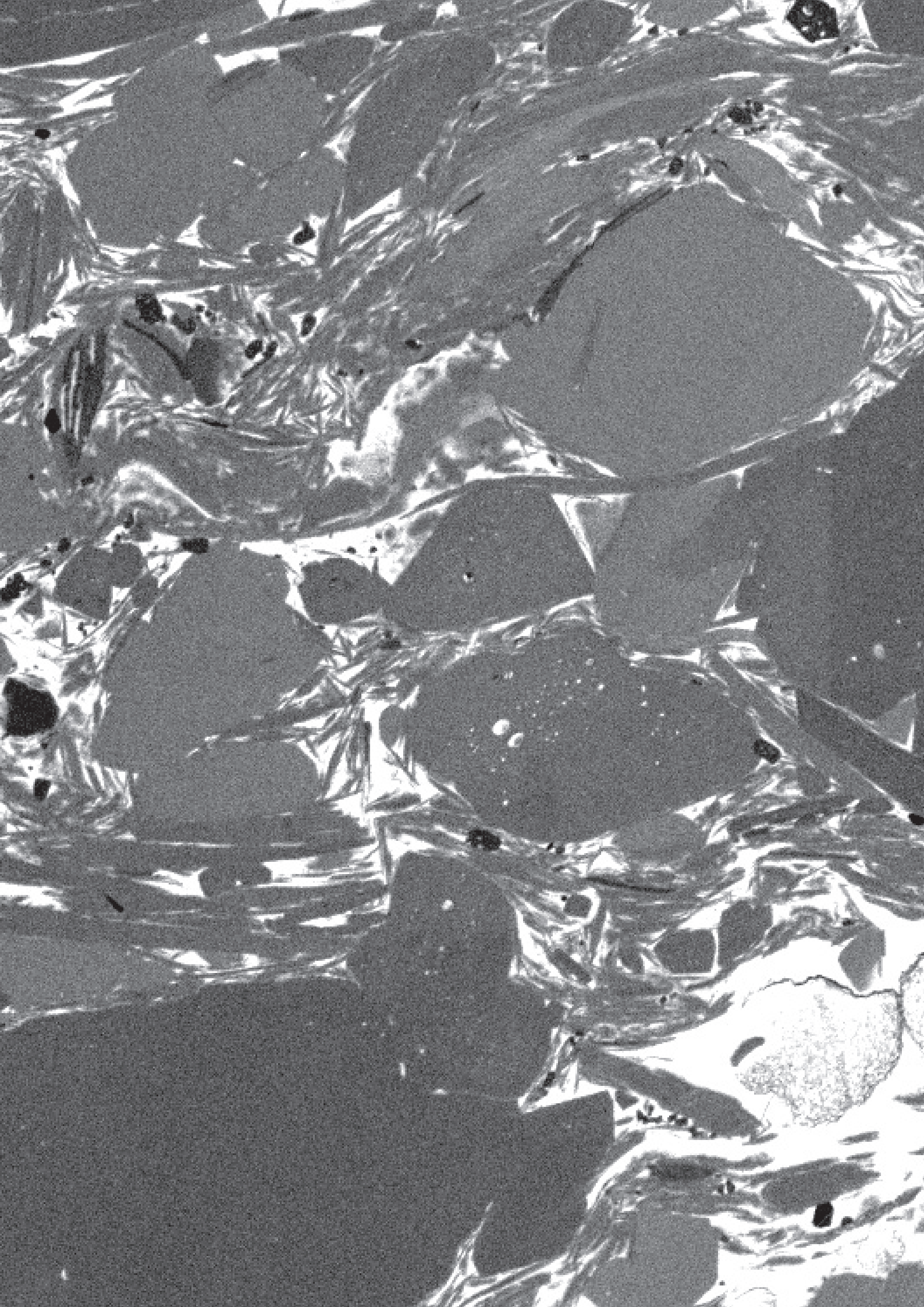




# Table of Contents

---

<b>Introduction</b>	<b>8</b>
<hr/>	
<b>Resources</b>	<b>8</b>
Human resources	8
Material and laboratory equipment	9
<hr/>	
<b>Research</b>	<b>10</b>
Laboratory testing	10
Numerical modelling	14
Ongoing research projects	17
<hr/>	
<b>Publications</b>	<b>19</b>
<hr/>	
<b>Scientific collaborations</b>	<b>20</b>
<hr/>	
<b>Media</b>	<b>20</b>
<hr/>	
<b>Conferences/workshops</b>	<b>21</b>
Organization of workshops and conferences	21
Participation to conferences and scientific events	23
<hr/>	
<b>Scientific boards and committees</b>	<b>24</b>
Editor in Chief	24
Member of Editorial Boards	24
Scientific and Expert Committees	24
Membership in Faculty Search committees for professor positions	25
<hr/>	
<b>Finances</b>	<b>26</b>





## **The Chair “Gaz Naturel”**

**- Petrosvibri aims at integrating and combining state-of-art research capacities to understand the involved geomechanical processes related to carbon dioxide (CO<sub>2</sub>) geological sequestration. The challenges of the Chair “Gaz Naturel” - Petrosvibri deal with understanding and prediction of the effects of the surrounding environment, mechanical and chemical changes, as well as cool effect during CO<sub>2</sub> injection and storage. The coupling between fluids transport, chemical reactions, and mechanics is analysed through an advanced experimental and numerical research.**

# Team

---

## One full professor



**Lyesse Laloui**, Chair professor of Geo-Engineering and CO<sub>2</sub> Storage at the École Polytechnique Fédérale de Lausanne (EPFL). He is the director of the Laboratory for Soil Mechanics as well as the director of the EPFL Civil Engineering Section. He has developed successful state of the art research approaches that cover the most productive and rapidly expanding areas in the field of geotechnical engineering. In particular, he has focused on the fundamental study of soils and man-made geo-systems with an emphasis on the mechanics of various interacting multi-scale and multi-physics phenomena. Laloui established an internationally recognized expertise in the areas of computational geo-mechanics, environmental geo-mechanics, and the mechanics of multiphase porous materials.

## One postdoctoral researcher



**Alberto Minardi** is a post-doctoral researcher at LMS-EPFL and is experimentally investigating the behaviour of shale caprocks. He joined the Chair in February 2018; before becoming a post-doctoral researcher, Alberto was a PhD student with LMS-EPFL and completed his thesis, entitled «Hydro-mechanical characterization of gas shales and Opalinus Clay shale in partially saturated conditions» early this year.

## Two PhD students



**Barnaby Fryer** earned his master's degree from TU Delft with his thesis focused on compositional dynamic multilevel multiscale reservoir simulation. He joined the Chair in January 2017 and during his first year developed a simulator which sequentially couples a finite volume flow and a finite element mechanics model allowing him to simulate poroelastic stress and pore pressure changes during subsurface fluid injection. Barnaby is currently developing a seismicity simulator which uses these pressures and stresses to predict the risk of inducing a large seismic event based on the properties of the various layers associated with the injection. The goal is to use this methodology to aid in site selection with regard to induced seismicity.



**Kim Taeheon** joined the Chair in October 2018. His research activities are focused on the analysis of rock-fluid interaction in the context of CO<sub>2</sub> storage. Before joining the LMS, he completed his master thesis on the interplay between interparticle friction, dilation, and strength at Imperial College London.

## Two technicians



**Patrick Dubey**, technical manager at LMS-EPFL, responsible for the help with the experimental equipment and specimens' preparation.



**Luc Morier-Genoud**, technical assistant at the LMS-EPFL, provides support to the experimental activities of the laboratory.

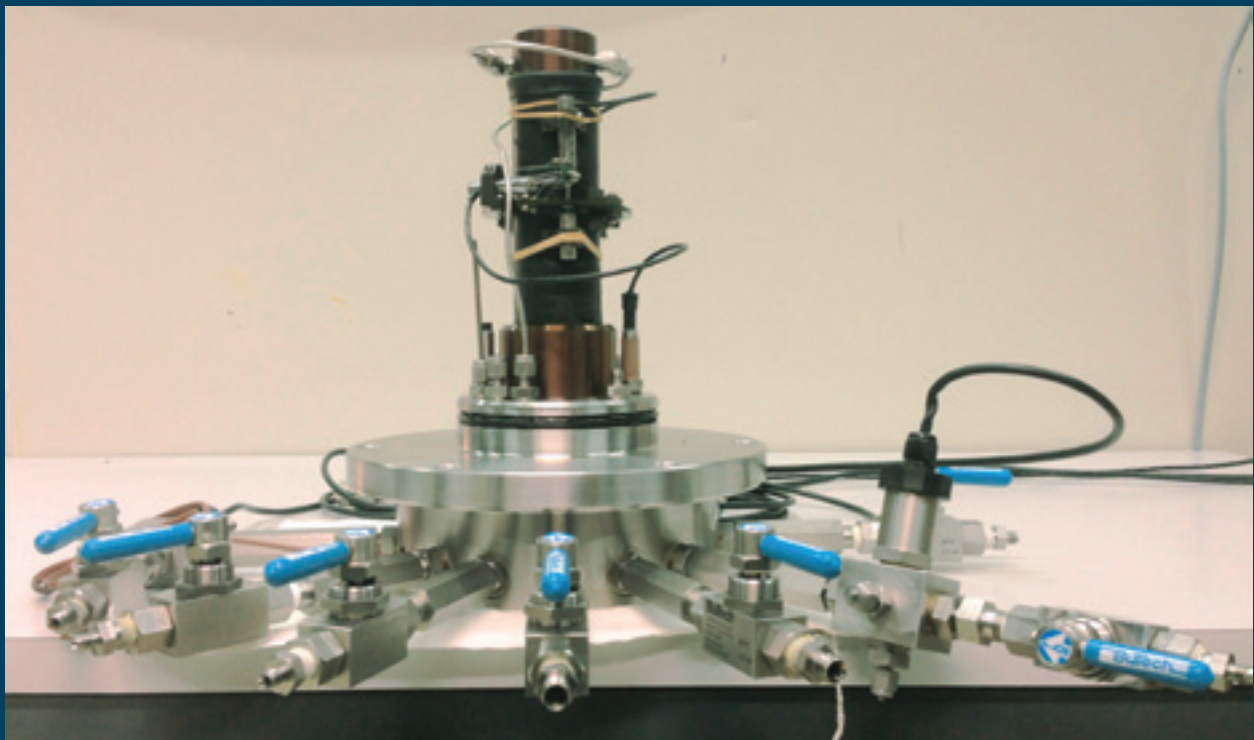


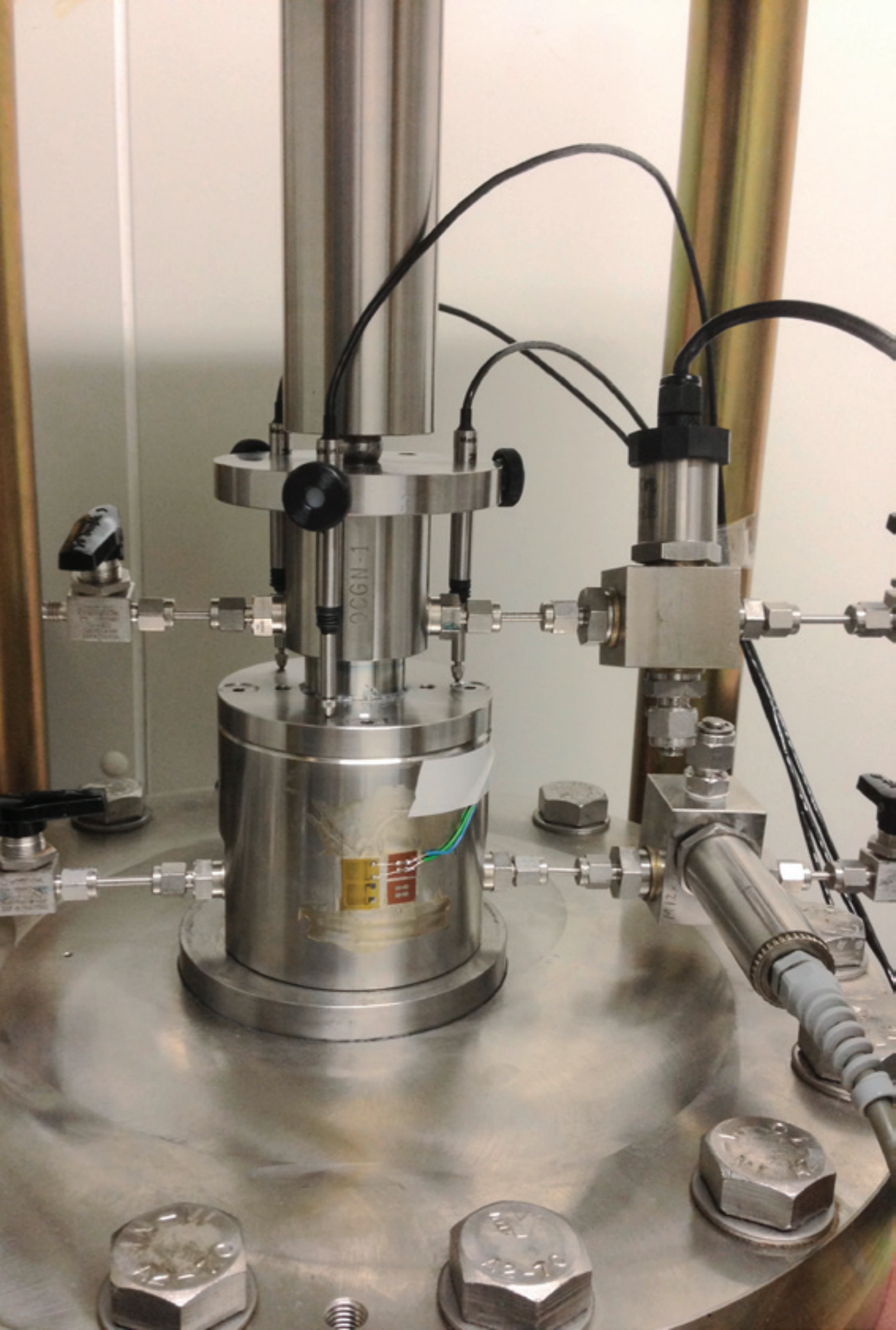
# Lab equipment

## Material and laboratory equipment

The personnel of the Chair “Gaz Naturel” – Petrosvibri makes regular use of the following material:

- Full office for postdoctoral researchers and two desks for the PhD students.
- One computer for each of the personnel.
- Software used for numerical analysis calculation.
- Advanced testing equipment to analyze the geomechanical behavior of materials in contact with  $\text{CO}_2$ . The equipment includes the following devices: triaxial cell and high-pressure oedometric cell placed in the thermostat room,  $\text{CO}_2$  syringe pump, and two triaxial cells at the Laboratory for Soil Mechanics (EPFL).







## Laboratory testing

Laboratory experiments were performed to analyse the geomechanical behaviour of a Swiss shale caprock (the Opalinus Clay) for the geological storage of CO<sub>2</sub>. In particular, the experimental work focused on the assessment of the sealing capacity of the material to CO<sub>2</sub> injection. The sealing capacity is usually quantified with the capillary entry-pressure, which represents the maximum CO<sub>2</sub> overpressure in the reservoir that the water saturated caprock can sustain. Different experimental methodologies can be adopted to evaluate the capillary entry-pressure of geomaterials. The low permeability of the Opalinus Clay, and the sensitivity of mechanical and transport properties to changes in water saturation represent the main challenges to be faced. The goal of the performed experimental investigation is not only the evaluation of the sealing capacity of the Opalinus Clay by measuring the capillary entry-pressure, but is also the analysis of the mechanical response of the material when subjected to CO<sub>2</sub> injection.

CO<sub>2</sub> injection experiments were carried out in the high-pressure oedometric cell designed at the Laboratory for Soil Mechanics. The testing strategy foresaw the saturation of specimens with water, the stepwise injection of CO<sub>2</sub> on one side (upstream) of the sample, while at the other side (downstream) of the sample the pressure evolution of CO<sub>2</sub> is monitored in a constant volume reservoir. The capillary entry-pressure is obtained as the difference between the CO<sub>2</sub> injection pressure and the initial pore water pressure in the sample when an increase of pressure is observed at the downstream side. Figure 1 illustrates the testing layout and the injection strategy adopted for the performed experimental analysis. (Figure 1)

An example of testing result is presented in Figure 2 that summarizes the hydro-mechanical response of the tested sample during the injection of CO<sub>2</sub> at the upstream side. The two graphs summarize the evolution in time of the CO<sub>2</sub> injection pressure at upstream side, the recorded CO<sub>2</sub> pressure at the downstream side (monitored with the pressure transducer), and the mechanical response of the sample in terms of measured axial displacements (positive displacement corresponds to compaction). The CO<sub>2</sub> injection lasted a total time of 11 days. (Figure 2)

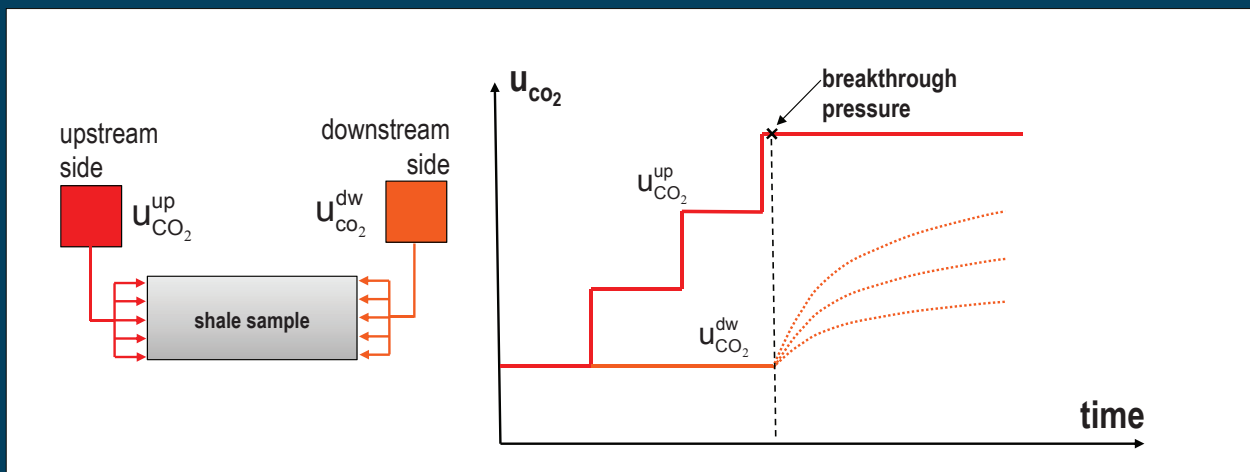
The hydraulic response illustrated in the graph a) is used to evaluate the capillary entry-pressure of the tested sample. During the first step where the upstream CO<sub>2</sub> pressure was increased to 4 MPa, the pressure at the downstream side did not exhibit any variation, meaning that the material behaved as perfect barrier capa-

ble to avoid the penetration and propagation of CO<sub>2</sub> in the sample. On the other hand, a slight increase of the downstream pressure is observed in the second step, where the CO<sub>2</sub> pressure was increased to 8 MPa at the upstream side. This aspect indicates that the capillary entry-pressure of the sample was exceeded during this step, and the CO<sub>2</sub> was able to penetrate and find a path across the sample to achieve the downstream side. This feature is confirmed in the third step, where the CO<sub>2</sub> pressure was increased to 12 MPa; in this case, the increase of pressure at the downstream side was even more significant compared to the previous step. Finally, during the last step where the injection pressure was decreased back to 8 MPa, a reduction of the pressure increase at the downstream side was observed. These outcomes allow the identification of the capillary entry-pressure in the second injection step (when the injection pressure was increased from 4 to 8 MPa), leading to a value in the range between 2 MPa and 6 MPa.

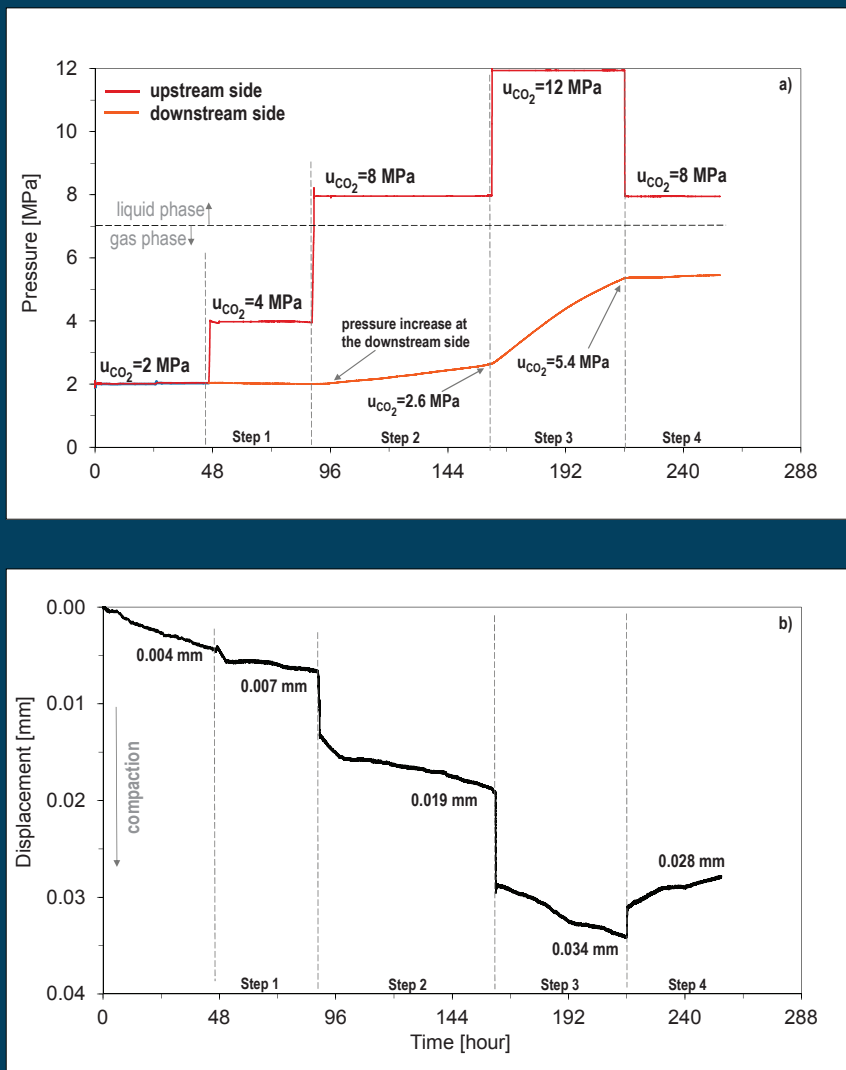
The graph b) in Figure 2 illustrates the mechanical response exhibited by the tested sample during the different injection steps. A compaction is observed in each step where the CO<sub>2</sub> pressure at the upstream side was increased. This compaction is strongly related to the development of capillary forces during the injection of CO<sub>2</sub> in the water saturated sample. Indeed, when a single fluid is present in the pore space of a geomaterial, an increase of the injection pressure is entirely transmitted to the fluid in the pore space, causing an expansion of the material due to a decrease of the effective stress. However, when two different fluids are present in the pore space of the material, capillary forces develop at the interface between the two fluids, and the pressure increase of the injected fluid (CO<sub>2</sub>) is not entirely transmitted to the pore fluid (water). The effect of the capillary forces is pulling the material's particles together leading to an overall compaction of the sample. A rough estimate of the capillary forces in geomaterials can be obtained with Young-Laplace equation, which relates the capillary pressure to the pore diameter and wettability with the assumption of a cylindrical capillary tube. In the case of the Opalinus Clay and more generally of shales, capillary forces may be significant (in the order of some MPa) due to the extremely small size of the pores (in the nanometer range). Of course this phenomenon has to be balanced with the CO<sub>2</sub>/water saturation of the sample. If most of the pore space is occupied by the CO<sub>2</sub>, the overall average increase of the pore pressure in the material prevails on the effect induced by the presence of capillary forces.

Before the penetration of CO<sub>2</sub> in the sample (during the first injection step to 4 MPa), the capillary forces only developed on the upstream boundary of the sample and





**Figure 1:** Testing layout (left) and example of pressure evolution (right) during CO<sub>2</sub> injection tests with constant volume CO<sub>2</sub> reservoir at the downstream side.



**Figure 2:** Hydro-mechanical response of the sample during the CO<sub>2</sub> injection phase of the test. a) upstream and downstream CO<sub>2</sub> pressures evolution, b) axial displacement (with cumulated values) experienced by the tested sample during the injection period.

they were able to perfectly sustain the CO<sub>2</sub> overpressure causing a small compaction of the material; this capillary barrier system was able to prevent the migration of CO<sub>2</sub> across the sample, and no pressure variations were observed at the downstream side. However, once the CO<sub>2</sub> is recovered at the downstream side (second step where the injection pressure was increased to 8 MPa), the capillary forces started to develop also inside the sample along the pathways that conveyed the CO<sub>2</sub> across the material. This feature led to a more pronounced compaction of the material in the second and third steps where the injection pressure was increased to 8 and 12 MPa. This observed behaviour suggests the hypothesis that the CO<sub>2</sub> was able to displace the water and penetrate in the material just along localized pathways that had lower water retention capabilities, leading to a partial desaturation of the sample. An opposite response was observed in the last step where the reduction in injection pressure led to the decrease of the capillary forces and the observed expansion of the material.

To further support the proposed interpretation of the observed mechanical response during the injection of CO<sub>2</sub> in the water saturated sample, a second CO<sub>2</sub> injection test was performed on the same sample but in unsaturated condition. To have the sample in unsaturated conditions, it was exposed to free air for about one month after dismantling the first test; after this period the water degree of saturation was 37%. Then, the sample was again mounted in the cell and loaded to 24 MPa of total axial stress without any contact with water. The CO<sub>2</sub> injection was then performed with the same procedure presented above; after the initial CO<sub>2</sub> injection to 2 MPa at both upstream and downstream sides, the injection pressure was again increased in three steps (to 4, 8, and 12 MPa) at upstream side, and finally decreased to 8 MPa in the last step. The duration of each step was also as much as possible similar to the injection in the saturated sample. (Figure 3)

Figure 3 shows a comparison of the observed hydro-mechanical response during the CO<sub>2</sub> injection between the two tests (saturated and unsaturated sample). The graphs a) and b) clearly illustrate the different hydro-mechanical behaviour of the Opalinus Clay when it is not fully saturated; in terms of sealing capacity, the CO<sub>2</sub> is indeed able to easily penetrate in the material and reach the downstream; few hours are sufficient for the pressure front to propagate across the entire unsaturated sample and equalize the entire system to the injection pressure. For this reason it is hard to observe in the graph b) a clear distinction between the upstream and downstream pressure evolution. The graphs c) and d) present the comparison in terms of mechanical response. When the material

is not saturated with water, the injection of CO<sub>2</sub> clearly induces an expansion of sample. As the amount of water in the pore space is smaller compared to the amount of CO<sub>2</sub>, the impact of the capillary forces on the mechanical behaviour is limited compared to the overall average increase of the pore pressure due to increase of the injection pressure. These results clearly indicate that the water saturation of the sample does not only affect the sealing capacity of the material, but also for the mechanical response exhibited by the Opalinus Clay during the injection of CO<sub>2</sub>.

Further experimental analyses are currently carried out at the Chair to investigate the impact of long-term exposure to CO<sub>2</sub> on mechanical and transport properties of the Opalinus Clay.

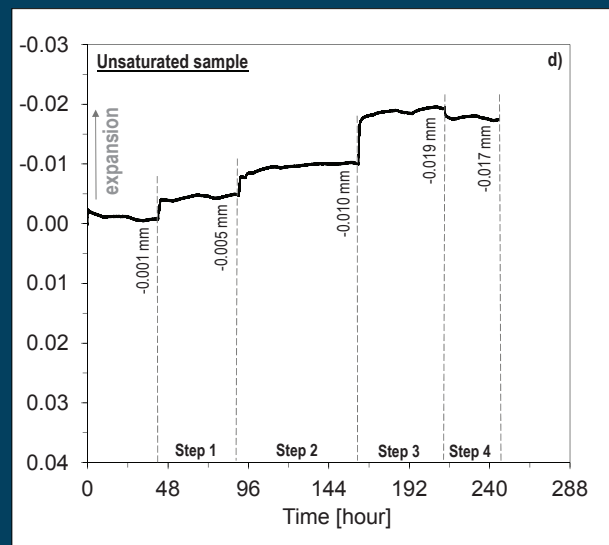
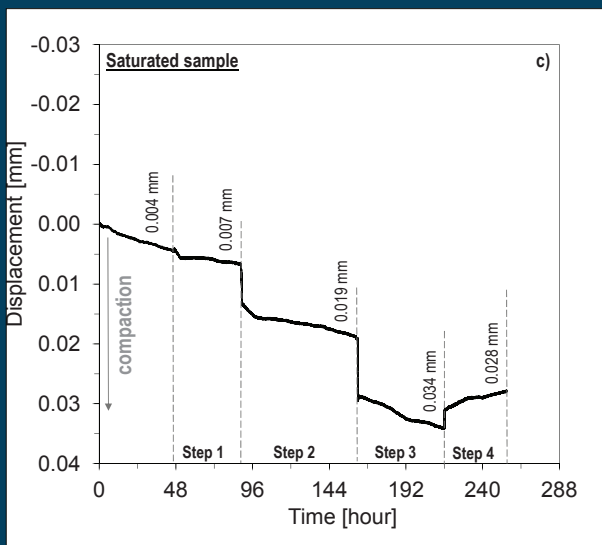
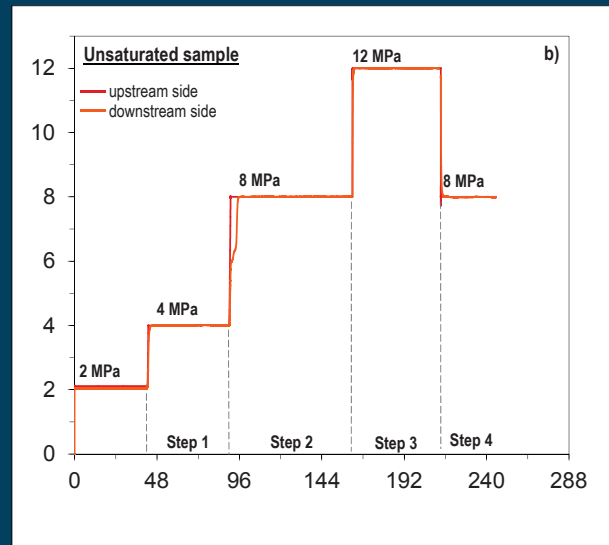
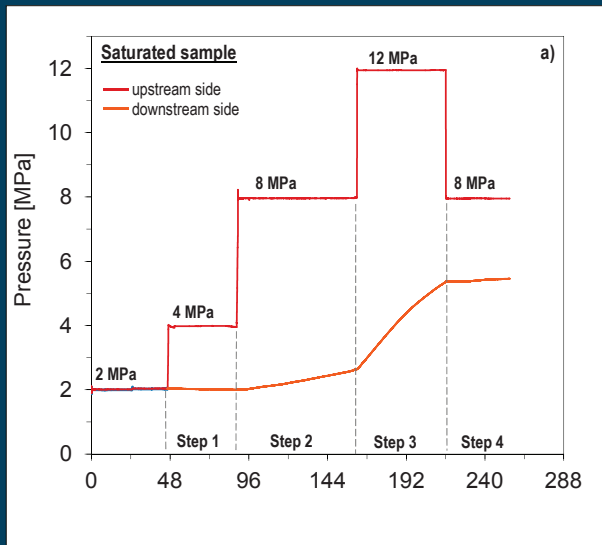
## Numerical modelling

Modelling work was performed based on the idea that the selection of injection horizons for CO<sub>2</sub> storage needs to honor the inherent differences of the lithologies that will be affected by this storage whilst respecting the reality that there is great uncertainty surrounding our knowledge of any specific subsurface site. Namely, the consideration of the different frictional properties of faults likely to be present in the different types of layers in the subsurface, the creation of a worst-case, yet realistic, stress profile, and the assumption that a well-oriented fault may exist at any location in the subsurface were all incorporated into a modelling approach to quantitatively assess the risk associated with a given injection site.

This approach is able to predict the aseismic or low magnitude seismic slip that occurs in the sedimentary intervals (i.e. the caprock and injection horizon). It also predicts a relatively large risk of a large seismic event associated with the underlying basement rock. The methodology therefore has utility in site selection where it can be used to assess the risk of a large induced seismic event at a proposed site.

The work on this modelling approach was begun last year and finished this year. It has been presented at two international conferences and is in the process of publication in the form of the conference proceedings of GHGT-14.

This year, the numerically modelling focus of the chair has turned to induced seismicity in fluid production scenarios. Using a sequentially coupled finite volume flow, finite element mechanical simulator, the poroelastic stress and pore pressure changes associated with fluid production are simulated for a general production scenario. This



**Figure 3:**  
Comparison of the hydraulic and mechanical response between the saturated a) and c) and unsaturated b) and d) sample during the CO<sub>2</sub> injection



# Research

---

pressure and stress changes are then connected to a previously developed seismicity model which is then able to predict the seismicity seen in field studies of this induced seismicity phenomena.

The novel idea of hydraulically fracturing the wellbore to reduce this induced seismicity was introduced by the chair this year. The idea is based on the fact that the stress changes (which are responsible for the induced seismicity seen in these scenarios) are incurred via the pore pressure gradient. A pore pressure gradient is required to produce fluid via the well and is largest near the wellbore. A hydraulic fracture greatly reduces the pore pressure gradient required to produce a certain amount of fluid. Therefore, in theory, a hydraulic fracture should be capable of reducing the induced stress changes that are occurring due to production. A reduction in the stress changes also implies a reduction in the induced seismicity.

The investigation of this idea was carried out by the chair this year. Indeed, it has been shown that hydraulic fractures are capable of reducing the induced stress changes caused by fluid production. They therefore are also capable of reducing the induced seismicity caused by this industrial activity. An example modelling result for a reverse faulting stress regime is shown in Figure 9. Note how the seismicity is predicted to occur above and below the reservoir in this stress regime as dictated by poroelasticity in Figure 9a. In Figure 9b, the differences in seismicity rate are shown for the standard case, with no hydraulic stimulation, and the stimulated case. Clearly, the induced seismicity has been reduced by the fracturing treatment. (Figure 4)

It was further found that this methodology is particularly effective in reverse and strike-slip faulting stress regimes but only moderately effective in normal faulting stress regimes. It is important to note that the modelling results are for the same flow rate, so it is not necessarily the case that induced seismicity will be reduced by hydraulically fracturing a reservoir if the well is then produced at a higher rate. Further, it should be noted that hydraulically fracturing reservoirs has been seen to induce seismicity itself. Therefore, care should be taken when implementing this technique to counter induced seismicity.

This work cumulated into a public in the Journal of Geophysical Research: Solid Earth. The journal publication also contained insight into optimal horizontal well orientation such that induced seismicity is reduced. In fact, it was found that wellbore orientation has a significant impact on the stresses induced. It was shown that induced seismicity is reduced when wells are drilled parallel to

the minimum principal stress in normal faulting stress regimes and parallel to the maximum principal stress in reverse faulting stress regimes. In strike-slip faulting stress regimes, it was shown that well direction has implications for the relative location of the induced seismicity.

Building upon this idea, the chair began investigating the effect of compaction-induced permeability loss on production induced seismicity. Because compaction leads to permeability loss, one intuitively imagines that this may have the opposite effect of a hydraulic fracture. As permeability is reduced, higher pore pressure gradients will be required to produce fluid. This implies that higher stresses will be induced. Especially significant will be the effect of inelastic compaction. Indeed, initially, compaction induced permeability loss is “near-elastic”, meaning that permeability losses are relatively small and largely reversible. At a certain point, however, compaction begins to occur largely inelastically, resulting in large, irreversible changes to permeability.

This effect was also investigated by the chair this year. This investigation was performed with a similar numerical model used to investigate the fracturing work mentioned above, except, this time, permeability’s dependence on mean effective stress was implemented, using results from literature. The result of the investigation was that compaction-induced permeability loss does indeed have implications for induced seismicity; however, this effect is small as long as compaction remains in the near-elastic domain. If compaction begins to occur inelastically, large permeability losses are incurred. This can result in very large stress changes and ultimately significant increases in induced seismicity rate. It is therefore recommended that operators develop a good understanding of their reservoir rock and monitor their drawdowns such that this type of compaction can be avoided.

A further finding of this work was based on the idea that a large determining factor for inelastic compaction is differential stress. The larger the differential stress the more likely compaction is to occur inelastically. Stress changes due to production from a horizontal well are not isotropic, so this implies that wellbore direction has influence on how quickly a reservoir begins to compact inelastically. This was investigated in this work and it was found that, in order to avoid inelastic compaction, wellbores should be drilled parallel to the the maximum horizontal stress. An example of this finding is shown in Figure 5.

This work has been submitted to Pure and Applied Geophysics for publication in their journal and is currently under review.

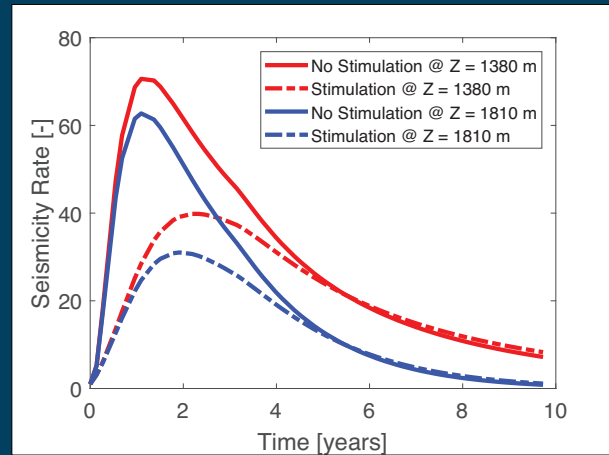
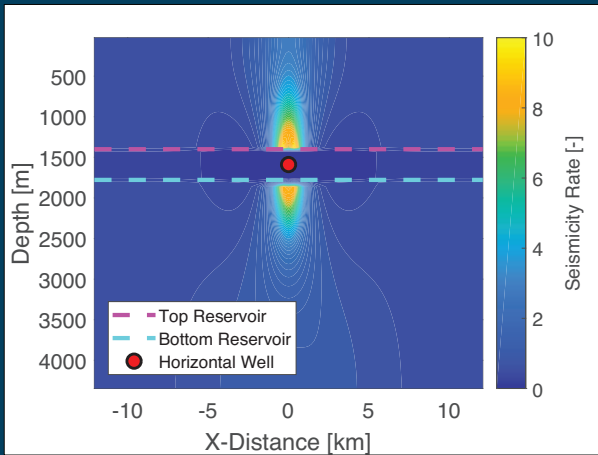


Figure 4 : The (a) seismicity rate induced by fluid production when no stimulation treatment is performed. The (b) effect of stimulation on the seismicity rate at locations directly above and directly below the reservoir. Note how stimulation reduced the seismicity rate.

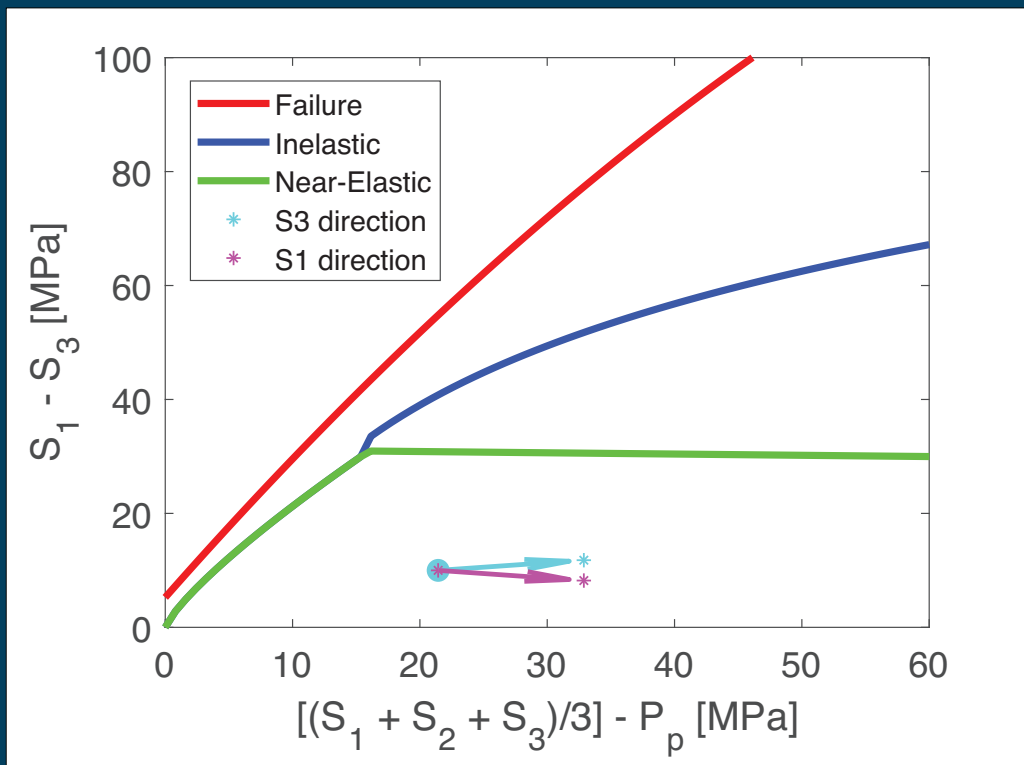


Figure 5 : The initial stress state of the reservoir in a strike-slip faulting stress regime is represented by the base of the arrows. During production, the stress state of the near-wellbore region moves to the right. Two cases are shown, the light blue represents the case that the well is drilled parallel to the minimum horizontal stress

and the pink represents the case that the well is drilled parallel to the maximum horizontal stress. The green line represents the transition from near-elastic to inelastic compaction. Clearly, drilling the well parallel to the maximum horizontal stress keeps the reservoir away from the inelastic compaction region.

# Ongoing research projects



## Swiss Competence Center for energy research – Supply of Electricity

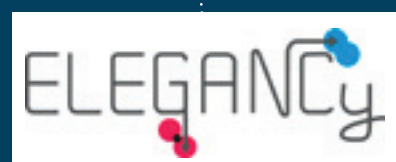
The Chair is actively participating to the activities of the SCCER-SoE. The goal of the consortium is to perform innovative research in the context of geo-energy and hydropower. In particular the Chair is contributing to the work package 1 (WP1), leaded by Prof. Lyesse Laloui, with scientific activities in the context of carbon dioxide sequestration. Experimental studies are currently carried out to investigate shaly caprock formations. Numerical analyses are also performed to forecast seismicity induced by fluid injection and production.



## ELEGANCY project - Enabling a Low-Carbon Economy via Hydrogen and CCS

This project is part of the European initiative ACT (Accelerating CCS Technologies) to facilitate research, development, and innovation in the context of carbon capture storage (CCS) and utilization. The Elegancy project aims at combining CCS with hydrogen production; as large quantities of carbon dioxide ( $\text{CO}_2$ ) are obtained during the production of hydrogen, CCS is needed to keep the hydrogen energy source clean. The Swiss partners are participating to the Elegancy project through the SCCER-SoE by performing an in-situ experiment to assess the sealing capacity and integrity of a faulted caprock formation. The experiment is planned in the Mont Terri URL and aims at analysing the physical phenomena controlling the migration of  $\text{CO}_2$ -rich brine in the faulted caprock, along with the impact on mechanical and transport properties of the damaged caprock.

The Chair is contributing to the project with experimental activities at the laboratory scale to characterize the material (Opalinus Clay) extracted from the drilled boreholes for injection and monitoring. Parameters governing the mechanical response and the transport of  $\text{CO}_2$ -rich brine in the Opalinus Clay are investigated to provide consistent data for the performance of numerical simulation. The experimental activities are carried out in collaboration with ETH Zurich, Imperial College London, and McGill University.







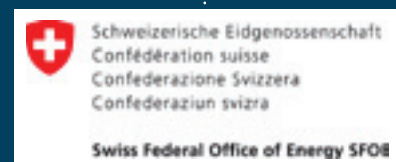
### **CS-C Experiment: Experimental assessment of shale properties for safe geological CO<sub>2</sub> storage**

The Chair contributes to the research at underground rock laboratory in Mont Terri (Switzerland). The CS-C is supported by the members of the Mont Terri consortium: Swisstopo (Switzerland) and FANC (Belgium). The aim of the project is to improve the knowledge on the capillary sealing capacity of caprock shale formations for the underground storage of CO<sub>2</sub>. The research activities carried out by the Chair during 2018 were merged with the work performed for the ELEGANCY project. This decision will allow the Chair to establish significant advancement in the assessment of the Opalinus Clay sealing capacity for CO<sub>2</sub> geological storage.



### **Using modelling-monitoring loop to demonstrate storage performance in terms of seismicity induced by fluid injection**

Waste water injection in sedimentary sequences has been seen to cause induced seismicity in the basement rocks below. This seismicity may also pose a threat to potential CO<sub>2</sub> sequestration operations. Switzerland, especially, has already had problems with induced seismicity. The most notable case being in Basel in 2006, when magnitude 3+ earthquakes were induced during EGS stimulation and were enough to bring the project to a halt. Clearly, the magnitude 5+ earthquakes seen during waste water injection can therefore also pose a threat. The chair «Gaz Naturel» performs quantitative seismic risk analysis accounting for the lithology differences between the sedimentary sequences where injection is occurring and the crystalline basement rock below.



### **CO<sub>2</sub> injection in permeable geological media for EOR**

The Chair was involved in a scientific collaboration with the French research institute "IFP Energies nouvelles". The aim of the partnership was the study the impact of CO<sub>2</sub> injection on the geochemical and geomechanical characteristic of shale gas reservoir materials for the purpose of enhance hydrocarbon recovery.



## Publications

### Books

- Ferrari A, Laloui L (2018). Energy geotechnics, proceeding of the International Symposium on Energy Geotechnics. Springer Series in Geomechanics and geoengineering.

### Journal papers

- Ferrari A, Minardi A, Ewy R, Laloui L (2018). Gas shales testing in controlled partially saturated conditions. International Journal of Rock Mechanics and Mining Sciences, 107:110-9.
- Fryer B, Siddiqi G, Laloui (2018). Reservoir Stimulation's Effect on Depletion-Induced Seismicity. Journal of Geophysical Research: Solid Earth, 123.
- Minardi A, Ferrari A, Ewy R, Laloui L (2018). The impact of the volumetric swelling behavior on the water uptake of gas shale. Journal of Natural Gas Science and Engineering 49(1):132-44.
- Minardi A, Ferrari A, Ewy R, Laloui L (2018). Nonlinear elastic response of partially saturated gas shales in uniaxial compression. Rock Mechanics and Rock Engineering, 1-12.

### Conference papers

- Laloui L, Ferrari A, Minardi A, Ewy R (2018). Laboratory testing of gas shales in unsaturated conditions. Proceedings of the 7th international conference on unsaturated soils, Hong-Kong.
- Minardi A, Ferrari A, Ewy R, Laloui L (2018). Elastic behavior of partially saturated gas shales during unloading - reloading cycles in uniaxial compression. Proceedings of the 7th international conference on unsaturated soils, Hong-Kong.
- Minardi A, Ferrari A, Ewy R, Laloui L (2018). Gas shale water imbibition tests with controlled suction technique – In International Symposium on Energy Geotechnics, pp. 250-257, Springer, Cham.

## Scientific collaborations

### Invitation

The department of Civil Engineering and Transportation at the University of Hohai invited Prof. Lyesse Laloui for his expertise in the field of geo-energy and appointed him as Advisory Professor.

### Master project

A master project entitled “Feasibility and evaluation study of the CO<sub>2</sub> injection in low permeability porous medium in purposes of geological storage and EGR” was carried out at the EPFL in collaboration with the French institute of petroleum “IFP Energie nouvelles”. The work was performed by the student Heithem Lejmi under the supervision of Dr Alberto Minardi. The goal of the work was to analyze the possible geochemical and geomechanical effects on shales from unconventional reservoirs due to exposure to CO<sub>2</sub>. Obtained experimental results demonstrated an impact on the dynamic mechanical properties, as well as an alteration of the adsorbed gas. These preliminary results support the possibility of using CO<sub>2</sub> as fluid for enhance gas recovery.

### Master project

A master project entitled “Experimentation on hydraulic fracturing and investigation on fault slip stability during injection” was concluded at the EPFL by the student Arabelle de Saussure under the supervision of Barnaby Fryer. The goal of the work was to analyze the possible interaction between the fluids injection for fracturing purposes and the induced seismicity. Part of the study related to laboratory tests on crack initiation, propagation, and coalescence, was performed at the Massachusetts Institute of Technology during spring 2018. The project built upon the numerical work performed last year by a previous master student.

# Media

## “Tout un Monde” RTS

Prof. Laloui interviewed by RTS programme “Tout un Monde” to talk about the role the geo-energies in the context of Swiss Energy Strategy 2050.



## L'Extension

Highlights of the research conducted at the Chaire Gaz Naturel – Pertrosvibri at EPFL in the October 2018 edition of L'Extension.



## Le Temps

Prof. Laloui explained the key role of CO<sub>2</sub> sequestration to reduce greenhouse gases concentration in the atmosphere in an article on the newspaper Le Temps: “Remettre le CO<sub>2</sub> d'où il vient!”.



## RTS un

Prof. Laloui talked about the contribution of CO<sub>2</sub> sequestration to counteract climate change on December 2018 on the TV channel “RTS un”. « Dans le journal de la «RTS», le professeur Lyesse Laloui du laboratoire de mécanique des sols de l'EPFL parle de la séquestration de CO<sub>2</sub>, une des techniques de géoingénierie qui permet de lutter contre le réchauffement climatique. »



# Conferences/workshops

## Organization of workshops and conferences

The Chair organized the following three main events in 2018

### Winter School on GEOMECHANICS and ENERGY for the ENVIRONMENT

23th-25th January 2018, Villar-sur-Ollon, Switzerland

Lectures were given by internationally renowned experts who are members of the editorial board of the Geomechanics for Energy and the Environment journal: Tomasz Hueckel (Duke University), Ronaldo I. Borja (Stanford University), Emmanuel Detournay (University of Minnesota). The school was attended by 22 participants.



### Geo-energies Workshop SCCER-SoE 5th June 2018, Lausanne (EPFL campus), Switzerland

The workshop aimed at gathering young researchers (PhD and postdocs) working in the geo-energies package of the SCCER-SoE. 40 people attended the workshop, 14 scientific talks were delivered, and 8 different research groups were represented. The research activities carried out in the work package 1 of the SCCER-SoE are playing a fundamental role towards the performance of the pilot project for deep geothermal energy and CO<sub>2</sub> sequestration.

### International Symposium on Energy Geotechnics

25th-28th September 2018, Lausanne (Swisstech Convention Center), Switzerland

The aim of the symposium was to cover a wide range of topics in energy geotechnics, including energy geostructures, energy geostorage, thermo-hydro-chemo-mechanical behaviour of geomaterials, unconventional resources, hydraulic stimulation, induced seismicity, CO<sub>2</sub> geological storage, and nuclear waste disposal as well as topics such as tower and offshore foundations. The proceedings of the conference are available in the Springer Series in Geomechanics and Geoengineering.



#### Key number of the event

9	12	33	159	250	35
mini-symposia	lectures	technical sessions	presentations	participants	countries



## Participation in conferences and scientific events

### The Chair was involved in the following conferences in 2018

#### Prof. L. Laloui was involved in the following scientific committees:

- Convener of the **16th Swiss Geoscience Meeting**, session “Shale-Gas, CO<sub>2</sub> Storage and Deep Geothermal Energy”. Bern, Switzerland, November 2018.
- Member of the International Technical Committee of **AP-UNSAT2019 – 7th Asia-Pacific Conference on Unsaturated Soils**, August 23-25, 2019, Nagoya, Japan

#### Prof. L. Laloui delivered the following lectures in 2018:

- **Les Géo-énergies**. Energissima, Bulle (Switzerland), April 2018
- **Gas shales: geomechanical challenges and analysis**. ComGeo IV, Assisi (Italy), May 2018.
- **CO<sub>2</sub> sequestration: challenges and solutions**. R&D day GazNat, Lausanne (Switzerland), May 2018.
- **Laboratory testing of gas shales in unsaturated conditions**. The 7th International Conference on unsaturated Soils, HKUST (Hong-Kong), August 2018.
- **Highlights of the geo-energy activities**. SCCER-SoE annual conference, Luzern (Switzerland), September 2018.

#### The Personnel of the Chair participated in the following workshops and conferences during 2018:

- CS-C experiment: impact of CO<sub>2</sub> injection on the hydromechanical behaviour of Opalinus Clay, Minardi A., Mont Terri Meeting. Porrentruy (Switzerland), February 2018.
- Hazard and risk assessment of large seismic events owing to fluid injection, Fryer B. ComGeo IV. Assisi (Italy), May 2018.
- Reservoir stimulation's effect on depletion-induced seismicity, Fryer B., SCCER-SoE annual conference. Lucern (Switzerland). September 2018.
- Mechanical response of Opalinus Clay during CO<sub>2</sub> injection, Minardi A., SCCER-SoE annual conference. Lucern (Switzerland). September 2018.
- Elastic behaviour of partially saturated gas shales during unloading-reloading cycles in uniaxial compression, Minardi A., The 7th International Conference on unsaturated Soils, HKUST (Hong-Kong), August 2018.
- The effect of permeability loss on induced seismicity during depletion-induced reservoir compaction, Fryer B., International Symposium on Energy Geotechnics 2018 (SEG-2018), Lausanne (Switzerland), September 2018.
- Gas shale water imbibition tests with controlled suction technique, Minardi A., International Symposium on Energy Geotechnics 2018 (SEG-2018), Lausanne (Switzerland), September 2018.
- Hazard and risk assessment of large seismic events owing to CO<sub>2</sub> injection, Fryer B. GHGT, Melbourne (Australia), October 2018.
- Reservoir stimulation and its effect on depletion-induced seismicity, Fryer B. 16th Swiss geoscience meeting, Bern (Switzerland), November 2018.
- Experimental investigation on the sealing capacity of Opalinus Clay to CO<sub>2</sub> injection, Minardi A., 16th Swiss geoscience meeting, Bern (Switzerland), November 2018.

# Scientific boards and committees

## Editor in Chief

- Geomechanics for Energy and the Environment – Elsevier (2014-present)

## Member of Editorial Boards

- Associate Editorial Board of Frontiers in Carbon Capture, Storage, and Utilization, a section of Frontiers in Energy Research (2013-present)
- Acta Geotechnica (2011-present)
- Chinese Journal of Geotechnical Engineering (2008-present)
- European Journal of Environmental and Civil Engineering (2005-present)
- Journal of Coupled Systems and Multiscale Dynamics (2013-present)
- International Journal for Numerical and Analytical Methods in Geomechanics (2013-present)
- Underground Space (2016-present)

## Membership in Faculty Search committees for professor positions

**Prof. L. Laloui is serving in the followings committees:**

- Member of Faculty Search Committee for a position of Professor in Hydraulics at EPFL (2017).
- Member of Faculty Search Committee for a position of Professor in Indoor Environmental Quality and Building Controls at EPFL (2016-2017).
- Member of Faculty Search Committee for a position of Professor in Transportation systems at EPFL (2016-2017).

## Scientific and Expert Committees

**Prof. L. Laloui is acting in the following organizations:**

■ Leader of Work Package Geo-Energies in the executive Committee of the Swiss Competence Center for Energy Research – Supply of Electricity (SCCER-SoE). Work Package 1, Geo-energies, is intended to enable Switzerland to achieve the goals of Energy Strategy 2050. This involves the development of technology that will allow for the generation of around 4.4 TWh of electricity per year. (<http://www.sccer-soe.ch/en/research/geo-energies/overview/>)

■ Member of the international evaluation panel of the six main Civil and Geological Engineering Departments in Portugal. Fundação para a Ciência e a Tecnologia (FCT) is the Portuguese public agency that supports science, technology and innovation, in all scientific domains, under the responsibility of the Ministry for Science, Technology and Higher Education. Since 1996, the FCT launches every four years a national evaluation of research and development units in all areas of knowledge.

■ Co-founder of the International Joint Research Center for Energy Geotechnics in China, a new international technology cooperation platform. The Energy Geotechnical Center actively contributes to the research and application of energy geostructures. It focuses on the development and industrialization of this breakthrough technology that combines the underground infrastructure growth with exploitation of the shallow geothermal energy. IJRC leverages interdisciplinary knowledge in order to integrate intelligent constructions and new energy challenges.

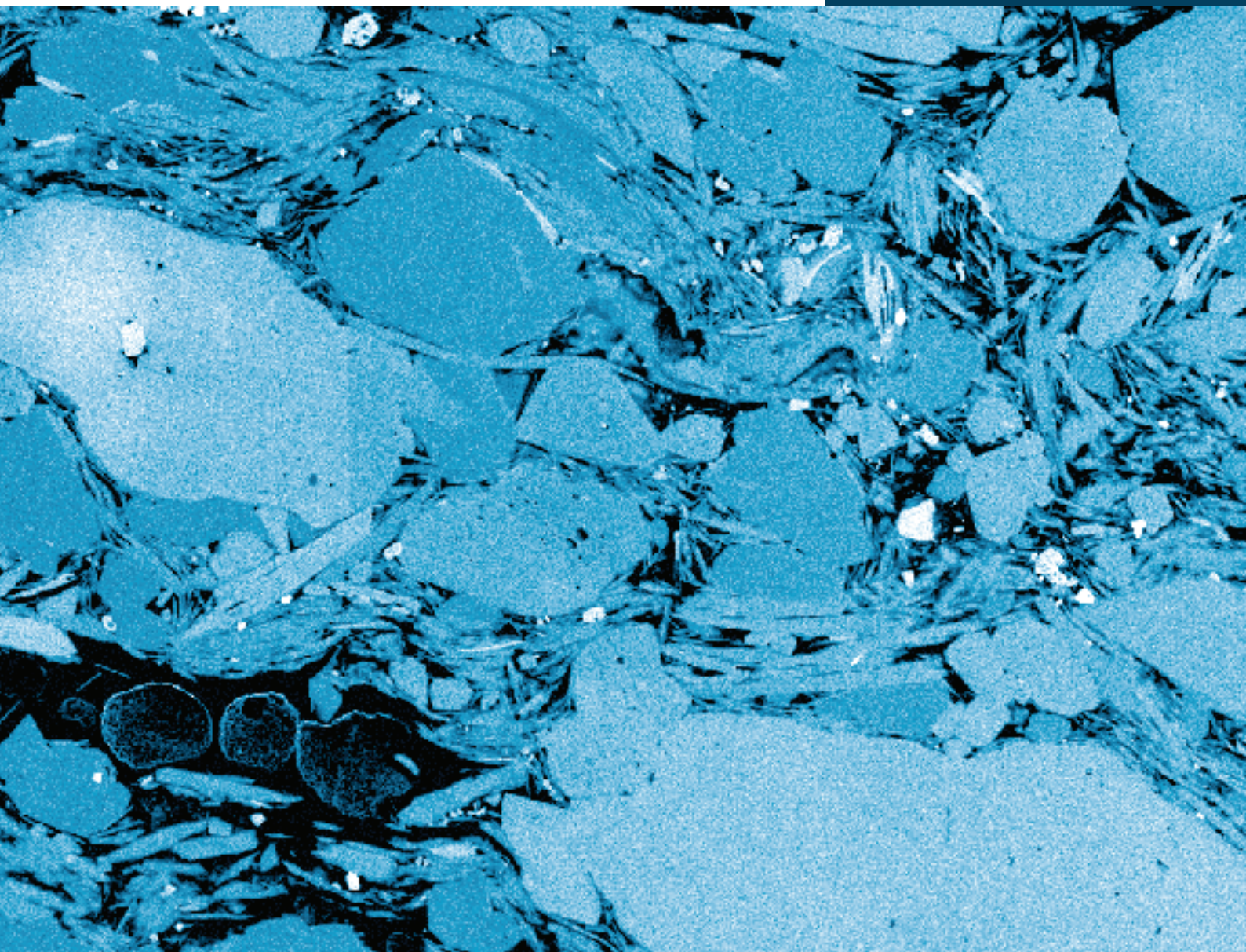
■ Scientific Council of CISM. The International Centre for Mechanical Sciences, is a non-profit organization located in Udine (Italy). Its principal activity is the organization of seminars, workshops, symposia and conferences for sharing knowledge and applications of mechanical sciences.

■ Executive Committee representative for the Government of Switzerland in the International Energy Agency Greenhouse R&D Technology Collaboration Program (2016-present)

■ Vice-Chair of the TC101 “Laboratory Stress Strain Strength - Testing of Geomaterials” of the International Society for Soil Mechanics and Geotechnical Engineering (2013-2017; Core member 2010-2013). Member of the selection committee for the Bishop Lecture (2013).







[chaire-gaz-naturel.epfl.ch](http://chaire-gaz-naturel.epfl.ch)

École Polytechnique Fédérale de Lausanne  
Laboratory for Soil Mechanics  
Director: Prof. Lyesse Laloui

CONTACT  
EPFL-LMS, GC Station 18  
CH 1015 Lausanne, Switzerland  
Phone +41 21 693 23 15  
[lms@epfl.ch](mailto:lms@epfl.ch)