

# International Symposium on Energy Geotechnics 2018

Under the auspices of Technical Committee 308 of ISSMGE

September 25-28  
Lausanne, Switzerland

Chairmen  
Lyesse Laloui & Alessio Ferrari



ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

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PROGRAMME BOOK

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# Location

The symposium will take place in the Swiss Federal Institute of Technology in Lausanne (EPFL), Switzerland at the SwissTech Convention Center (STCC) on campus.

The most convenient location to fly into to reach Lausanne is Geneva Airport, which is about 1 hour away from Lausanne by train.

The other suitable option would be Zurich Airport which is about 2.5 hours from Lausanne, again by train.

The STCC can be reached from either airport by taking the train to either Lausanne Gare or Renens VD and then taking the metro.

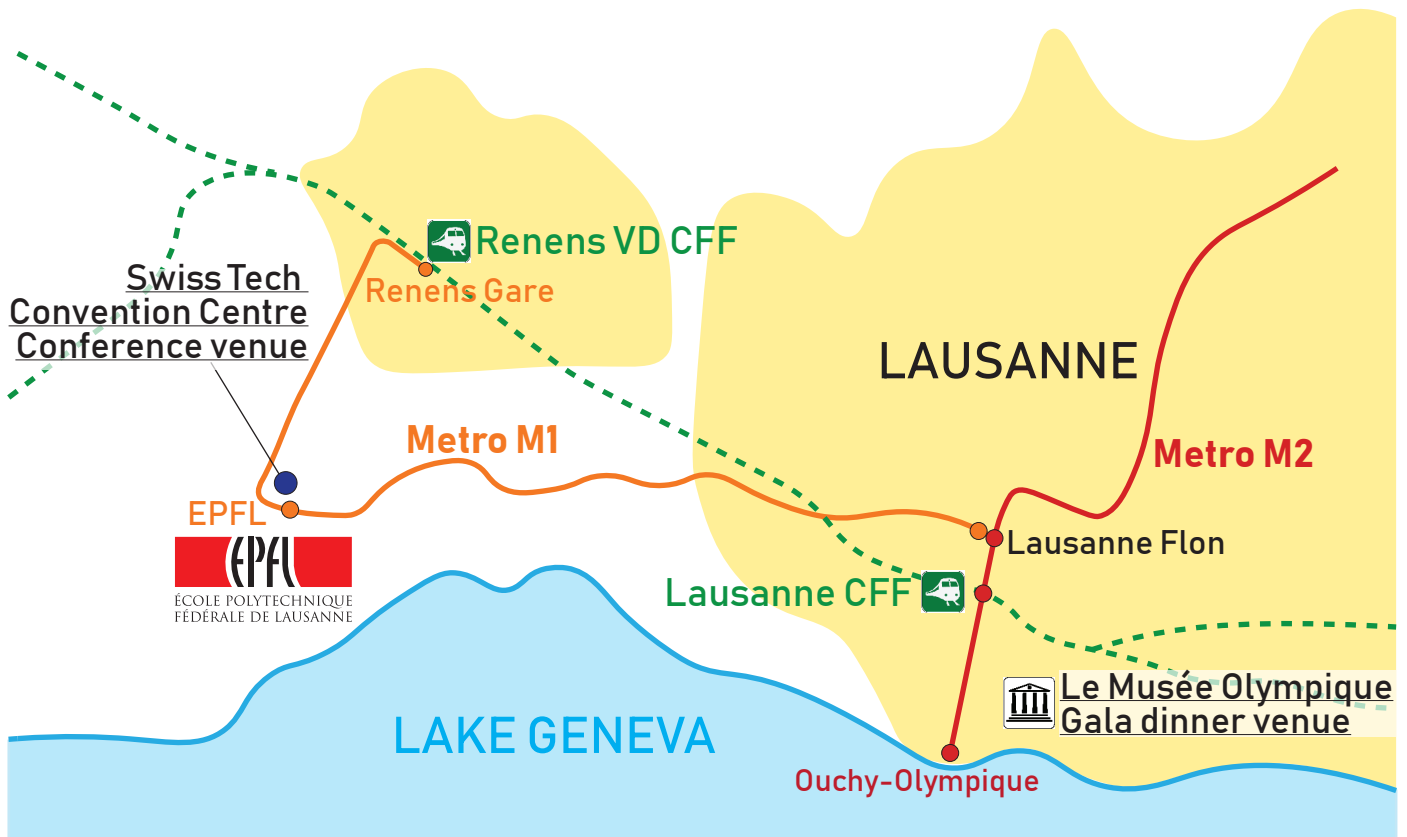
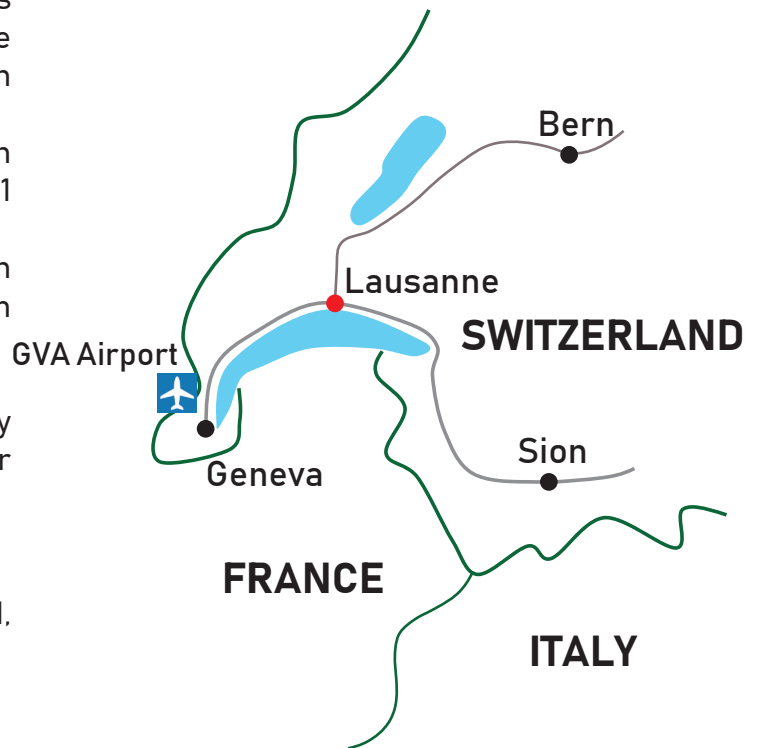
From Lausanne train station to STCC:  
Metro M2 to Lausanne Flon and then Metro M1, direction Renens Gare, stop EPFL.

From Renens VD train station to STCC:  
Metro M1, direction Lausanne Flon, stop EPFL.

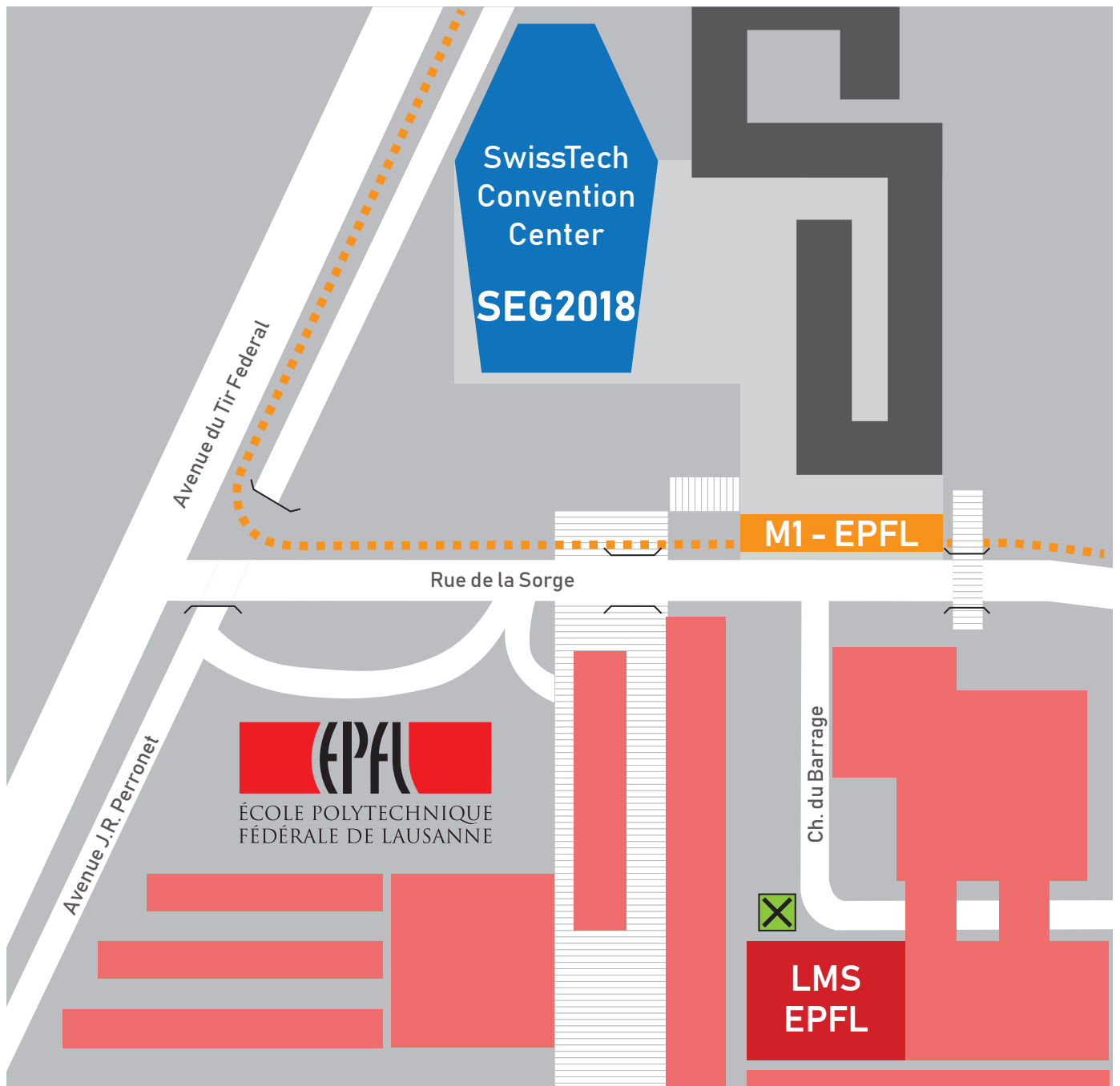
## Addresses:

Conference venue: SwissTech Convention Center, Route Louis-Favre 2, 1024 Ecublens

Gala dinner venue: Le Musée Olympique, Quai d'Ouchy 1, 1006 Lausanne



# Campus map



 Laboratory visit & Mont-Terri visit meeting point

# General information

## Emergency contact numbers

If for any reason you are in need of emergency assistance, please dial :

General emergency	112	Police	117
Fire Service	118	Ambulance	144

## SEG2018 Hotline

If you need any help, please call the symposium hotline at:

**SEG2018 Hotline: +41 079 5702114**

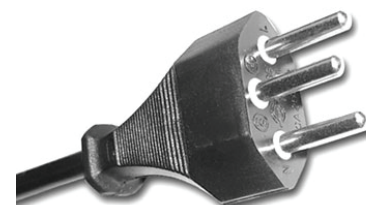
## Oral presentation

Authors are kindly asked to provide the presentation at least half day before the session. A technical stand will be located close to the registration desk for uploading the presentations. A laser pointer will be provided.

As SEG will be operating on a tight schedule, it is important that the presenters stick to their allotted presentation slots of 12 minutes each (excluding 3 minutes for questions). To facilitate this, a reminder bell will be rung 11 minutes after the presentation has started to signal to the presenter that time is nearly up. Then, a double ring at 12 minutes will signal to the presenter and the audience that the presentation is over.

## Practical Information

The electric current used in Switzerland is 230 Volts AC. Wall outlets are unique to Switzerland (hexagonal three pin plug). You can find adaptors at the airport or in Post offices.



## Public Transportation

EPFL campus is connected to Renens Station and Lausanne Flon by the metro line M1, which is connected to the metro line M2 who reached Lausanne Station and Ouchy. There is also a bus line 31 who reached “Renens Gare Sud” and EPFL “Argand”.

## #SEGeo2018 Twitter Hashtag

You can follow the Twitter profile of LMS-EPFL (@geomecha\_EPFL) for news and updates on the Symposium. Please use #SEGeo2018 in your tweets, so all tweets can be quickly found and read.

# Social Events

## Welcome reception

Swiss Tech Convention Center

Tuesday Sep. 25

6:45 – 7:30 PM

The welcome reception will take place at the SwissTech Convention Center beginning at 6:45 PM after the opening ceremony on September 25th.

## Gala Dinner

Le Musée Olympique

Thursday Sep. 27

7:45 – 11:00 PM

The gala dinner will take place at the Olympic Museum on the second full day of the conference. The evening will begin with cocktails before we all dive into the banquet dinner. Before the dinner (starting from 6:30 PM), the invited participants will have the great opportunity to visit the Museum and live an exciting olympic experience.



The Olympic Museum, situated right at the edge of Lake Geneva, opened its doors in 1993, as a unique window on the world of sports. However, the Olympic history of Lausanne actually dates back more than a century. At its 100th anniversary, the International Olympic Committee made Lausanne the official Olympic Capital, a unique and prestigious title.

The gala dinner venue can be easily reached from the metro station (Metro M2, Ouchy Olympique Terminus) walking less than 10 minutes on the Geneva Lake shore.

**Monday  
September 24**

**Tuesday  
September 25**

**Wednesday  
September 26**

**Thursday  
September 27**

**Friday  
September 28**

**Saturday  
September 29**

		Registration			Registration			Registration				
9:00	Registration	Keynote Lecture Jonny Rutqvist, Berkeley Lab			Keynote Lecture Jean Desroches, Schlumberger			Keynote Lecture Antonio Gens, UPC			9:00	
10:00		Keynote Lecture Lyesse Laloui, EPFL			Keynote Lecture Stefan Wiemer, ETHZ			Feature Lecture Maria Victoria Villar, CIEMAT			10:00	
11:00		COST GABI Lecture Sébastien Burlon, Terrasol Setec			Feature Lecture Marie Violay, EPFL			Feature Lecture Marcelo Sanchez, Texas A&M			11:00	
		Coffee break			Coffee break			Coffee break				
12:00		MS 1A Analysis and Design of Energy Geostrutures	MS 1B Hydraulic Stimulation in Energy Geotechnics	MS 1C Multi-Scale And Multi-Physics Processes in Shales and Soils	TS 5A Energy Geostrutures	TS 5B Gas Hydrate Sediments	TS 5C THMC Behavior of Geomaterials	TS 9A Geotechnics for Offshore Energy Applications	MS 9B Gas Production from Hydrate-Bearing Sediments	MS 9C Computational Waste Management in Geomechanics	Mont-Terri Underground Rock Laboratory Visit (optional)	
13:00	COST GABI short course  How to plan a successful thermoactive geostructure design? (optional)	Lunch			Meeting of the ISSMGE - TC308 Energy Geotechnics		Lunch		Lunch			
14:00		MS 2A Analysis and Design of Energy Geostrutures	MS 2B Hydraulic Stimulation in Energy Geotechnics	MS 2C THMC Behavior of Earth Materials	TS 6A Energy Geostrutures	MS 6B Induced Seismicity	TS 6C THMC Behavior of Geomaterials	TS 10A Other Geotechnics activities related to the Energy Sector	MS 10B Gas Production from Hydrate-Bearing Sediments	MS 10C Current Advances and Challenges Associated with Geological Disposal		
15:00		MS 3A Analysis and Design of Energy Geostrutures	MS 3B CO <sub>2</sub> Geological Storage	MS 3C THMC Energy Geostorage	TS 7A Energy Geostrutures	MS 7B Induced Seismicity	TS 7C THMC Behavior of Geomaterials	TS 11A Hydraulic Stimulation	MS 11B Gas Production from Hydrate-Bearing Sediments	MS 11C Current Advances and Challenges Associated with Geological Disposal		
16:00	Visit of the Laboratory for Soil Mechanics at EPFL (optional)	Coffee break			Coffee break			Coffee break				
17:00		TS 4A Energy Geostrutures	MS 4B CO <sub>2</sub> Geological Storage	TS 4C THMC Behaviour of Geomaterials	TS 8A Shallow Energy Geostorage	MS 8B Induced Seismicity	TS 8C THMC Behavior of Geomaterials	Closing Lecture Paul Bossart, Swisstopo				
18:00	Opening Ceremony Opening Lecture J. Carlos Santamarina, KAUST	Innovation Hub Presentation, exhibition and round table discussions										
19:00	COST GABI Lecture Fleur Loveridge, Uni Leeds											
	Welcome Reception											
20:00	GETE Editorial Board meeting				Gala Dinner at the Olympic Museum							

# Tuesday - September 25

## Opening Ceremony

5:15 - 6:45 PM

**Lyesse Laloui**

5:15 PM

EPFL, Switzerland and Co-Chair of the SEG 2018 Symposium

**Alessio Ferrari**

EPFL, Switzerland and Co-Chair of the SEG 2018 Symposium

**Marcelo Sanchez**

Texas A&M University and Chair of ISSMGE TC308

**Laurent Pitteloud**

President of the Swiss Geotechnical Association

**J. Carlos Santamarina**

5:30 PM

KAUST, Saudi Arabia

### **Fractured rock in energy geotechnics**

Energy resources and energy waste geostorage involve fractured rock masses in most cases. Fractures control all the physical properties, in particular the geoplumbing of the formation; yet, most laboratory and field studies focus on the intact rock. The presentation starts with fracture formation (ductile-brittle transition, layered-bound fractures) and fracture densities encountered in some reservoirs. Then, we review elastic properties (3D stress field and frequency effects), and thermal properties. Emphasis is placed on fluid flow, including: conductivity and transmissivity (the effect of the stress field and dilation, and consequences on stimulation), mixed fluid conditions, reactive fluids and fines migration. Finally, we explore alternatives for reservoir simulation in fractured rocks.

**Fleur Loveridge**

6:15 PM

Uni Leeds, England

### **Urban heat storage using structure and infrastructure foundations**

Heat provision in the UK accounts for around one third of all greenhouse gas emissions and 40% of energy consumption, with similar figures across mainland Europe. While recent progress has been made to decarbonise electricity generation, the majority of heating provision comes from the direct burning of fossil fuels. It is therefore clear that ground heat storage is essential for decarbonisation of heat. Urban ground heat storage systems require a ground heat exchanger (GHE) connected to a heat pump and a low temperature building heating delivery system. GHEs comprise a length of buried heat transfer pipes, which contain a circulating fluid. As the carbon density for electricity (needed to run the heat and circulation pumps) has fallen, so potential emissions savings has increased dramatically. In urban areas, GHEs are typically special purpose boreholes. However, drilling is expensive and high capital cost is a key barrier to uptake. But dual use of buried foundations and other structures removes the need for special purpose drilling. Piled foundations used as GHE were first developed in the 1980's, but are now becoming more routine and initial standardisation has occurred. But, there remains major opportunities to use other underground infrastructure for thermal energy transfer and storage. Retaining walls, tunnels and water/waste water pipes can all potentially be used as so called energy geostructures. This lecture will review the state of the art in the thermal assessment and design of a range of energy geostructures. It will consider what methods are readily available in academia and in practice and examine the barriers to future uptake of the technology. The lecture will draw on UK, EU and International projects, including the work of COST Action GABI and TC308.



# Wednesday – September 26

## Keynote and Feature Lectures

9:00 – 11:00 AM

**Jonny Rutqvist**

9:00 AM

Lawrence Berkeley National Laboratory, USA

### **“Fault activation, seismicity and leakage in geologic CO<sub>2</sub> sequestration”**

The potential for activating faults associated with geologic carbon sequestration is currently receiving increased attention among CO<sub>2</sub> sequestration stakeholders as an issue of concern both related to induced seismicity and CO<sub>2</sub> leakage. In the light of these concerns, findings from recent modeling studies and field observations are summarized with emphasis on CO<sub>2</sub> injection and storage in deep sedimentary formations. The model simulations demonstrate the importance of the in situ stress field (magnitude and orientation) and injection location relative to the fault, as well as the critical importance of fault properties. It is shown that a seismic event large enough to be felt by humans requires a brittle fault with kilometer sized continuous permeability that allows for pressurization of a sufficiently large fault patch before rupture. Heterogeneous fault properties which are commonly encountered in faults intersecting multilayered shale/sandstone sequences effectively reduce the likelihood of inducing felt seismicity and also effectively impede upward CO<sub>2</sub> leakage. A number of simulations show that even a sizable seismic event that could be felt may not be capable of opening a new permeable flow path across an overlying caprock and is very unlikely to cross a system of multiple overlying caprock units. These modeling studies and an increasing number of field observations correlating deep fluid injection with induced seismicity, show the importance of the site investigation to characterize in situ stress and rock properties. It may be critical to avoid brittle rock such as crystalline basement or sites in hard and brittle sedimentary sequences that are more prone to injection-induced seismicity and permanent damage.

**Lyesse Laloui**

9:45 AM

EPFL, Switzerland

### **“Analysis, Design And Application Of Energy Geostructures From The Building To The City Scale”**

This study focuses on the analysis, design and application of energy geostructures for the structural support and the energy supply of built environments, from the building scale to the city scale. The work is based on the results of full-scale in situ tests as well as theoretical analyses addressing fundamental aspects of the multiphysical behaviour of energy geostructures. The analysis and design of energy piles, energy walls and energy tunnels is treated and simplified yet effective design tools for such geostructures are presented. Aspects of primary importance for maximising the energy, geotechnical and structural performance of energy geostructures are presented, and solutions to address this challenge are proposed. Examples of practical analyses and design of energy geostructures from the building to the city scale are described and concluding remarks are highlighted. The goal of this lecture is to increase the confidence of engineers, architects, urban project managers and municipalities on the effectiveness and performance of energy geostructures.

**Sébastien Burlon**

10:30 AM

Setec-Terrasol, France

### **COST GABI Lecture: “GABI: a common European initiative for Geothermal Applications for Buildings and Infrastructure”**

The COST ACTION TU1405 GABI (shallow Geothermal Applications for Buildings and Infrastructure) has been launched in 2015 with the objective to build a new European network of researchers and engineers to address the challenges of thermoactive geostructures in terms of thermal and mechanical design. In thermoactive structures, heat exchangers are integrated in the elements of the structure that interface with the ground, such as foundations, tunnels and diaphragm walls. This technique is also particularly attractive because of the inherent cost savings involved in combining a required structural component with the harvesting of geothermal energy. Based on multidisciplinary approaches, this group has the ambition to develop collective understanding, share techniques, facilities and data, and work jointly in disseminating the obtained results across Europe. This lecture includes the main results obtained by this group: THM ground characterisation, thermal and mechanical design of thermoactive structures, interactions between thermoactive structures and other constructions at the scale of the district.

# Wednesday – September 26

1<sup>st</sup> SESSION

11:30 – 12:45 AM

## 1.A Mini-Symposium : Room 3

### Analysis and Design of Energy Geostructures

Organized by S. Burlon, Terrasol Setec; G. Biscontin, Cambridge University

- N. Makasis The application of retaining walls and slabs as energy structures in underground train stations
- X. Bao Large scale model tests and numerical investigations on thermo-mechanical behavior of energy pile in saturated clay
- K.S Abubakar Inlet & Outlet Pipe Heat Interaction in a Contiguous Flight Auger (CFA) Pile
- M. Sutman Load-Transfer Approach for Modeling the Cyclic ThermoMechanical Behaviour of Energy Piles
- E. Sailer Numerical modelling of thermo-active shafts

## 1.B Mini-Symposium : Room 4

### Hydraulic Stimulation in Energy Geotechnics: from Research to Practice

Organized by B. Lecampion, École Polytechnique Fédérale de Lausanne

- J. Desroches Revisiting sleeve fracturing for stress characterization
- H. Zia Modelling planar 3D hydraulic fracture propagation in materials with anisotropic fracture toughness
- F.H. Cornet The use of shear motions for the stimulation of EGS reservoirs
- E. Sarris Investigation of the Influence of Diffusion on the Closure Stress on Particles for Wellbore Strengthening Applications
- N. Dutler Preliminary results of six decameter-scale hydraulic fracturing (HF) experiments at the Grimsel Test Site (GTS)

## 1.C Mini-Symposium : Room 5

### A Multi-Disciplinary Approach to Multi-Scale and Multi-Physics Processes in Shales and Soils

Organized by E. Romero, Universitat Politècnica de Catalunya; G. Musso, Politecnico di Torino; C. Jommi, Politecnico di Milano

- J.M. Espitia Lopez Behaviour of shales under uniaxial compression through suction paths
- G. Della Vecchia A coupled approach for the simulation of HF treatments in low permeability reservoirs
- M. Rosone The residual shear strength of the shaly and sandy facies of the Opalinus Clay
- I.C. Bourg Chemo-mechanical coupling in fine-grained soils and sedimentary rocks
- L. Gonzalez Blanco Effect of heterogeneity on gas transport in compacted MX-80 bentonite

# Wednesday – September 26

2<sup>nd</sup> SESSION

2:00 – 3:15 PM

## 2.A Mini-Symposium: Room 3

### Analysis and Design of Energy Geostructures

Organized by S. Burlon, Terrasol Setec; G. Biscontin, Cambridge University

- J. Zannin Thermal charts and mechanical aspects on Energy Walls
- N.P. Lopez Acosta Numerical analysis of the thermo-mechanical behavior of an energy pile in Mexico
- W. Dongyuan Static Load Testing of Short Pile and FEA Simulations for Utility-Scale Solar Energy Project
- N. Woodman Evaluating the applicability of the radial approximation for pile heat exchangers
- A.F. Rotta Loria Analytical interaction factor models for energy pile groups

## 2.B Mini-Symposium: Room 4

### Hydraulic Stimulation in Energy Geotechnics: from Research to Practice

Organized by B. Lecampion, École Polytechnique Fédérale de Lausanne

- S. Salimzadeh Hydraulic Fracturing In Layered Media
  - I. Tomac Proppant Flow and Transport in a Narrow Fracture in Turbulent Flow Regime
- R. Rached Hydraulic fracturing in pre-fractured media
- M. Risyad Naturally Fractured Basement Reservoir Potential Quantification from Fracture Model and Petrophysical Analysis by Leveraging Geostatistics and Seismic Interpretation: A Case Study in Jabung Block, South Sumatra Basin
- J. Maury Modeling of the stress field: from regional to reservoir scale

## 2.C Mini-Symposium: Room 5

### THMC Behavior of Earth Materials

Organized by S. L. Abdelaziz, Stony Brook University; A. Bouazza, Monash University

- Li Yanling Boundary value level simulation of monotonic and cyclic thermal oedometer tests on natural sensitive clay
  - A. Gajo A time marching scheme for injection in a deformable reservoir saturated by three immiscible fluids
- Y.S. Kim Thermal conductivity of controlled low strength material (CLSM)
- M. Sedighi Elevated temperature effects on microstructure of compacted smectite
- J. McCartney Impact of drained heating and cooling on undrained shear strength of normally consolidated clay

# Wednesday – September 26

3<sup>rd</sup> SESSION

3:15 – 4:15 PM

## 3.A Mini-Symposium: Room 3

### Analysis and Design of Energy Geostrutures

Organized by S. Burlon, Terrasol Setec; G. Biscontin, Cambridge University

- A. Lazaros Assessment and comparison of soil thermal characteristics by laboratory measurements
- A. Di Donna Preliminary assessment of energy walls efficiency under different underground scenarios
  - A. Takai Laboratory tests on thermal improvement of soft clay under elevated temperatures
- B. Cousin Feasibility and energy performance of an energy segmental lining for a subway tunnel

## 3.B Mini-Symposium: Room 4

### CO<sub>2</sub> Geological Storage

Organized by J.-M. Pereira, École des Ponts ParisTech

- B. Orlic Effects of batch-wise CO<sub>2</sub> injection on well integrity: a numerical model of cement interface debonding
- Yixiang Gan Numerical Simulation of Liquid Patch Formation and Retention in Porous Media
- A.P. Rinaldi Deep fracture zone reactivation during CO<sub>2</sub> storage at In Salah (Algeria) – a review of recent modeling studies
- J.M. Pereira Analysis of modified cement paste in the context of CO<sub>2</sub> geological storage

## 3.C Mini-Symposium: Room 5

### THMC Energy Geostorage

Organized by F. Wuttke, Kiel University; D. Smeulders, Eindhoven University;

S.Bauer, Kiel University

- W.T. Pfeiffer Hydraulic effects during large-scale hydrogen storage in porous formations
- A.S. Sattari A new lattice element method (LEM) with integrated interface elements to determine the effective thermal conductivity of rock solids under thermo-mechanical processes
- H. Hailemariam Thermal cyclic stability analysis of porous heat storage materials
- D. Smeulders Underground storage of latent heat: Theory and experiments

# Wednesday – September 26

4<sup>th</sup> SESSION

4:45 – 6:00 PM

## 4.A Technical Session : Room 3

### Energy Geostructures

- M. Oliaei Advanced Finite Difference Method For Study Energy Piles Behavior in Temperature Dependent Soils
- F. Rognon Feasibility study on the implementation of geothermal tunnel segmental lining in the lot 3 tunnel on railway Line 16 of the Grand Paris Express
- D.D. Cortes Smart ground-source borehole heat exchanger backfills: A numerical study
- R. Houhou Experimental Study of the Uplift Resistance of Energy Piles in Soft Clay
- D. Zhang Thermo-mechanical behavior of geothermal PHC pile

## 4.B Mini-Symposium: Room 4

### CO<sub>2</sub> Geological Storage

Organized by J.-M. Pereira, École des Ponts ParisTech

- T. S. Yun Role of Reynolds Number in Two-Phase Fluid Flow
- L. Zhang Numerical simulation of CO<sub>2</sub> injection into Lower Tuscaloosa Co<sub>2</sub> storage reservoir in Mississippi, USA with experimentally validated modeling parameters
- M. Abdel-Mohsen Advanced Mineral Carbonation: An Approach to Accelerate CO<sub>2</sub> Sequestration Using Steel production wastes and Integrated Fluidized Bed Reactor
- I. Gravaud Risk assessment for the reversible storage of O<sub>2</sub> and CO<sub>2</sub> in salt caverns for large-scale energy storage

## 4.C Technical Session : Room 5

### THMC Behavior of Geomaterials

- N. Sau THM behaviour of a deep Eocene clay during heating tests
- G. Melot Chemo-Hydro-Mechanical analysis of Bituminized Waste swelling due to water up-taking: Experimental and model comparisons
- H. Manman Chemo-mechanical Coupling of Subcritical Crack Propagation via Chemo-elasticity
- D. Seyedi Key parameters controlling thermo-hydro-mechanical pressurization in Callovo-Oxfordian claystone
- T. Nishimura Measurements of strain of bentonite-sand mixture in suction cycles

# Wednesday – September 26

Innovation Hub

6:00 – 8:00 PM

## Presentations and technology showcasing of the inventors and start-ups

6:00 PM

### TTI

Roman Bilak, Kerry Kristiansen, Guowei Xia

Terralog Technologies Inc. provides petroleum and environmental geomechanics services for sustainable resource development. The company developed a Slurry Fracture Injection (SFI) hydraulic fracturing technology, which has been applied to place oilfield wastes, biosolids, and contaminated soils in the deep subsurface.

### Jansen

Dietmar Alge, Benjamin Pernter, Benjamin Haymoz

JANSEN offers innovative solutions for geothermal energy exploitation by incorporating their 60 years of experience in plastic pipe production. The Swiss company promises reliability, high quality, and innovative solutions as well as significant reductions in the installation costs.

### 4EE

Gregorius Riyan Aditya, Guillermo A. Narsilio, Nikolas Makasis

4EE provides a complete solution, encompassing design, construction and optimisation of shallow geothermal systems at any scale which include large infrastructure projects, greenfield housing developments and new build commercial buildings that seek innovation recognition and benefits.

### ENERTUN: energy tunnel segmental lining

Marco Barla, Alessandra Insana, Matteo Baralis

ENERTUN is an improved precast segmental lining to be used for tunnels excavated by Tunnel Boring Machine (TBM) patented by Politecnico di Torino. The segments are made of concrete and equipped by a net of pipes through which a heat carrier fluid can circulate and exchange heat with the ground.

### MeduSoil: Earth bio-reinforcement solutions (EPFL spin-off)

Dimitrios Terzis

Medusoil's mission is to design and deliver solutions for earth reinforcement and stabilization through the innovative biochemically active carriers, developed and patented at EPFL, incorporating technical innovation, economic efficiency and environmental responsibility.

### KENOTEQ (Heriot-Watt University spin-off)

Gabriella Medero

KENOTEQ is a clean technology spin out company of Heriot-Watt University, specialising in high quality recycled building products. KENOTEQ's first product is an unfired construction brick made from 90% recycled demolition and construction waste, helping to drive waste reduction in the construction sector.

## Round table discussions with panel experts

7:15 PM

Anil Sethi (ETH Zurich, Chair of Entrepreneurship)

Andrea Crottini (EPF Lausanne, Technology Transfer and Intellectual Property Manager)

# Thursday – September 27

## Keynote and Feature Lectures

8:45 – 10:45 AM

Jean Desroches

8:45 AM

Schlumberger, France

### **“Hydraulic fracturing, more than a reservoir stimulation technique: from measuring stresses to mine preconditioning”**

Hydraulic fracturing has recently received a lot of attention, as it unlocked the production potential of hydrocarbon source rocks (aka “shales”). Hydraulic fracturing, however, has been a core technique for stimulating hydrocarbon production in oil and gas reservoirs for nearly 70 years, as it is the preferred means to create a permeable conduit in a tight rock formation. Furthermore, the associated knowledge and understanding that has been developed is now being used for rather different applications in the subsurface. In this lecture, a wide-ranging review of hydraulic fracturing will be attempted. We will first describe the coupled physical processes underlying the most basic expression of hydraulic fracturing: pressure-driven fluid flow, rock deformation, and creation of new fracture surface, and show that the coupling between these processes gives rise to a unique system, whose specificities have been carefully studied during the last 25 years – starting with the studies of dykes. A short venture will then be made in the associated transport of solids via suspensions of complex Non-Newtonian fluids, as the tailoring of these fluids is a key lever to achieve the desired geometry and conductivity of a hydraulic fracture. In the second part of this lecture, we will focus on lesser known, though potent, uses of the hydraulic fracturing technique: Small-scale hydraulic fracturing is the only direct method to measure stresses at great depth, through the combination of creation of new fractures and reopening of pre-existing fractures. Examples of estimating the complete state of stress through this technique will be discussed. The use of hydraulic fracturing in mining will be presented, not only to remove coal gas ahead of the mining front, but also to induce safe caving of the roof rock. Finally, the use of hydraulic fracturing in the context of geothermal reservoirs will be considered.

Stefan Wiemer

9:30 AM

ETH Zürich, Switzerland

### **“Tailor-made risk governance for induced seismicity of geothermal energy projects”**

Fully open or partly open geothermal systems can induce potentially damaging seismicity. How this seismicity should be addressed depends on the geothermal system, its operational characteristics, the geological context, exposed buildings, existing infrastructure and populations, and social concern. We have developed an initial screening tool, called Geothermal Risk of Induced seismicity Diagnosis (GRID), for estimating to what extent induced seismicity is of concern for a specific project. A framework for tailor-made risk governance measures is then recommended, including hazard and risk assessment, social site characterization, seismic monitoring, insurance, structural retrofitting, traffic light systems, information and outreach, and public and stakeholder engagement. In this presentation, I will first outline this framework and then focus on traffic light systems (TSL) that are today an essential ingredient of induced seismic risk management. Their simplicity and robustness make them indispensable components of future GeoEnergy projects at risk of inducing felt earthquakes. However, classical TLS are purely reactive and inherently heuristic. They do not take into account the wealth of information available in near real-time. We are currently developing the next generation of TLS, Adaptive Traffic Light Systems (ATLS), which are data driven, model-based and risk-based. In this presentation I will review the key ingredients of ATLS, discuss the performance based on retrospective analyses and the roadmap towards real-time applications.

Marie Violay

10:15 AM

EPFL, Switzerland

### **“Coupled Hydro-mechanical processes in fault zones, implications for deep geothermal reservoirs”**

Fluids play an important role in fault zone and in earthquakes generation. Fluid pressure reduces the normal effective stress, lowering the frictional strength of the fault, potentially triggering earthquake ruptures. Fluid injection induced earthquakes in deep geothermal reservoirs are direct evidence of the effect of fluid pressure on the fault strength. Although simple in theory, the mechanisms that govern the nucleation, propagation and arrest of these earthquakes remain poorly constrained, and our ability to assess the seismic hazard associated with induced events remains limited. Here, thanks to friction tests, we investigate the effect of fluid pressure and fluid thermo-physical properties on fault co-seismic weakening and healing. We demonstrate that in silicate-bearing rocks: at low fluid viscosity, during rupture acceleration, initial fault weakening is governed by the flash heating mechanism and is delayed in the presence of water. This mechanism is influenced by fluid thermophysical properties. Therefore, the presence of low viscosity fluids might delay or inhibit the rupture nucleation and propagation depending on pressure and temperature conditions; at high fluid viscosity, during rupture acceleration, the initial weakening mechanism is governed by elasto-hydrodynamic lubrication. For small slip events, high fluid viscosity increases the energy dissipated during rupture processes and might delay or inhibit the rupture propagation. As seismic slip increases, the fault becomes more prone to slip in presence of high viscous fluid; during rupture deceleration, fluid pressure enhanced frictional healing rate by water cooling. Obtaining a fundamental understanding of the dynamics of a fault system and its associated energy budget is important to assess the seismic hazard of induced earthquakes in

# Thursday – September 27

5<sup>th</sup> SESSION

11:15 – 12:30 AM

## 5.A Technical Session : Room 3

### Energy Geostructures

- F. Casini Interaction between photovoltaic panel foundation and frost heaving soils
- R. Saggi Base Displacement Response of Group of Geothermal Energy Piles
- M. Peltier Influence of airflow conditions and convective heat transfer coefficient on urban energy tunnels performance
- A.R. Vasilescu Impact of temperature cycles at soil – concrete interface for energy piles
- Y. Delerabee Numerical assessment of thermal performance and heat storage capacity of thermoactive geostructures

## 5.B Technical Session : Room 4

### Gas hydrate Sediments

- L. Yang Analysing the Effects of Inhomogeneity on the Permeability of Porous Media Containing Methane Hydrates
- R. Yan Modeling the behaviors of hydrate-bearing sediment at different pore pressure and temperature environment
- G. Han Migration and clogging of silty fines by two-phase flows and its effect on sediment permeability
- Y. Wu Simple Modelling of the Mechanical response of Methane Hydrate-bearing Sediments

## 5.C Technical Session : Room 5

### THMC Behavior of Geomaterials

- Y. Yukselen-Aksoy The Effect of Colemanite and Ulexite Additives on the Shear Strength Behavior of Sand-Bentonite Mixtures Under High Temperature
- E. Cassini A macroscopic chemo-mechanical model for smectite based materials from atomic Clay-Ions-Water interactions
- L. Douma Impact of water saturation on the mechanical properties and elastic anisotropy of the Whitby Mudstone
- K. Liu Evaluation of reconstruction and segmentation techniques on high temporal resolution  $\mu$ CT scans for geotechnical applications
- E. Gerolymatou Borehole stability in the brittle and ductile regime



# Thursday – September 27

6<sup>th</sup> SESSION

2:00 – 3:15 PM

## 6.A Technical Session: Room 3

### Energy Geostructures

- G. Kong Thermal response test of floating energy pile in China: Case study
- F. Villalobos Monitoring in a district heating pipeline system
- S.H. Lines Analysis of groundwater advection and ground-heat exchanger spacing on intermittent ground-source heat pump operation
- Y. Guo Numerical study on the long-term thermal performance and ground temperature variation of energy pile in multi-layered soil
- G.R. Aditya Full-scale instrumented residential ground source heat pump systems in Melbourne, Australia

## 6.B Mini-Symposium: Room 4

### Induced Seismicity

Organized by M. Violay, École Polytechnique Fédérale de Lausanne

- A. Mignan Autonomous decision-making against induced seismicity in deep fluid injections
- Y. Zhu Simulation on Reservoir-induced Seismicity Considering Thermo-hydro-mechanical Couplings
- C. Cornelio Fluid viscosity controls earthquakes nucleation
- C. Noël Experimental study of reservoir seismicity using different injection strategies
- M. Acosta Rock/fluid interaction during induced earthquakes: Where does frictional heat go?

## 6.C Technical Session: Room 5

### THMC Behavior of Geomaterials

- M. Ondrasik Simple method of rock pore structure determination presented with the most common rock types quarried in Slovakia
- A. Minardi Gas shale water imbibition tests with controlled suction technique
- E. Romero Exploring ice formation and migration in frozen soils
- M.M. Arzanfudi A Thermo-Hydro-Mechanical Model for Soil Freezing/Thawing
- X. Sun The comparison of MICP between two different bacteria strains in low temperature condition

# Thursday – September 27

7<sup>th</sup> SESSION

3:15 – 4:30 PM

## 7.A Technical Session: Room 3

### Energy Geostructures

- J. Epting Waste heat recovery – Considerations for the management of thermally polluted urban groundwater resources
- P. Conti Thermal characterization of energy pile dynamics
- X. Yu Development of a CO<sub>2</sub> Heat Pipe for Hydronic Heated Bridge Decks
- R. Debasree Numerical analysis of geothermal system for Delhi silt soil in India
- A.A. Garakani A Feasibility Study on Implementing the Energy Piles in Electric Power Industries

## 7.B Mini-Symposium: Room 4

### Induced Seismicity

Organized by M. Violay, École Polytechnique Fédérale de Lausanne

- B. Fryer The effect of permeability loss on induced seismicity during depletion-induced reservoir compaction
- M. Broccardo A Bayesian Hierarchical Framework for Induced Seismicity Hazard Associated with Deep Underground Fluid Injection
- P. Giacomel Experimental studies of frictional instabilities of basalts triggered by injection of pressurized H<sub>2</sub>O- and CO<sub>2</sub>- rich fluids for CO<sub>2</sub> storage purposes
- L. Cauchie Analysis of persistent seismic multiplets at the EGS reservoir of Soultz-Sous-Forêts, France
- E. Spagnuolo Frictional instability under fluid stimulation: insights from load-controlled experiments on pre-existing faults.

## 7.C Technical Session: Room 5

### THMC Behavior of Geomaterials

- Z. Ye Study on fracture evolution of unsaturated red clay during drying process
- N. Al-Mohamadi Time-dependent deformations of chalk marl under triaxial state of stress
- M. Zicarelli The permeable concrete: a low energy consumption solution for deep draining tranches
- A. Tuttolomondo An effective stress framework for clayey geomaterials
- I. Stefanou Combined role of the size of the microstructure and of Thermo-Hydro-Mechanical couplings on stability and fault reactivation

# Thursday – September 27

8<sup>th</sup> SESSION

5:00 – 6:15 PM

## 8.A Technical Session : Room 3

### Shallow Energy Geostorage

- E. Passaris Geomechanical analysis of salt caverns used for underground storage of hydrogen utilised in meeting peak energy demands
- E. Al Hajri Feasibility Study and Experimental Investigation of Heat and Mass Transfer in Dry and Moisturised Sand for Energy Savings
- L. Paci Geotechnical challenges for a High Temperature Energy Storage in the greater Copenhagen area (Zealand, Denmark)
- O. Pedchenko Long-term thermal performance of a borehole heat exchanger installed near an open fracture for a range of hydrogeological scenarios
- M. Schuck Experimental investigation of dynamic behaviour of borehole heat exchanger by gas sparging technology

## 8.B Mini-Symposium: Room 4

### Induced Seismicity

Organized by M. Violay, École Polytechnique Fédérale de Lausanne

- L. Villiger On the variability of the seismic response during multiple decameter-scale hydraulic stimulations
- C. Brooks Evaluating Ground Motion Prediction Equations Currently Used in North Sea Probabilistic Seismic Hazard Assessment with Consideration of Induced Seismicity
- C. Nussbaum Fault criticality and leakage below the Coulomb plastic limit: insights from hydraulic stimulations in the Opalinus Clay, Mont Terri rock lab., Switzerland
- M. Lesueur Three-scale multiphysics framework modelling fault reactivation
- Wei Wu Overpressured fluid injection and fault slip triggering

## 8.C Technical Session : Room 5

### THMC Behavior of Geomaterials

- S. Yu Experimental study on erosive effects of sodium hydroxide solution on compacted clay
- C. Lijie Experimental study on strength characteristics of red clay under different particle size of calcium carbonate
- T. Orlander Using Biot's coefficient in estimation of thermal conductivity of sandstones
- M. Pasand Modeling of oil transport in porous media using multiscale method with adaptive mesh refinement
- J.C. Santamarina The Hydro-Mechanical Response of Pre-Structured Reservoirs Subjected to Hydraulic Fracture

# Friday - September 28

## Keynote and Feature Lectures

9:00 – 10:45 AM

**Antonio Gens**

9:00 AM

Technical University of Catalonia, Spain

### “Underground research laboratories in nuclear waste containment”

The favoured long-term solution for the disposal of high-level radioactive waste generally involves the construction of deep geological repositories. The development of such facilities pose important challenges from the point of view of scientific understanding, rock exploration and engineering construction. The lecture reviews the significant role played by Underground Research Laboratories (URLs) in this field. The key functions of URLs comprise the characterization of the host rock and the potential effects of excavation, the demonstration of the feasibility of construction and operation of the repository, and the enhancement of the understanding of the complex coupled phenomena that will take place in such an environment. A review of the main URLs located in different countries and continents will be presented, distinguishing between generic laboratories and site-specific ones, since their operations exhibit a number of differences. Distinction will also be made between purpose-built laboratories from pre-existing ones where the laboratory has taken advantage of previously constructed facilities. The changing emphasis of the work performed in the laboratories as research has progressed over the years will also be discussed. Experiments in the URLs often have special characteristics that will be examined. For instance, some tests are carried out over (comparatively) very long periods, sometimes longer than a decade. Tests are also performed over a variety of scales involving, in some instances, full-scale disposal schemes. Some characteristic experiments will be reviewed focusing mainly in the hydro-mechanical and thermo-hydro-mechanical behaviour of seals, barriers and the near field. Observations obtained upon dismantling will be given special attention.

**María Victoria Villar**

9:45 AM

CIEMAT, Spain

### “Hydro-chemo-mechanical interactions in compacted bentonite”

The behaviour of a nuclear waste repository is determined to a large extent by the changes that may occur in the properties of the bentonite-based buffer as a result of the combined effects of the heat generated by the radioactive decay and of the water and solutes supplied by the surrounding rock. These thermo-hydraulic gradients lead to changes in the bentonite physical state (water content, dry density) and geochemistry (movement of soluble species by advection and diffusion, changes in the composition of the cation exchange complex), all of them affecting its hydro-mechanical behaviour. Some of the properties to be taken into account to assess the correct performance of the barrier are its permeability, water retention capacity and swelling ability, which in turn depend mainly on dry density, water content, temperature and the physico-chemical interactions between the clay particles and the pore fluid chemistry. The hydro-chemo-mechanical interactions that control the behaviour of the bentonite barrier system can be approached in complementary ways: i) Small-scale laboratory tests in which the influence of chemical factors (solution and bentonite geochemistry) on bentonite hydro-mechanical properties is checked. These allow to identify major factors and look for fundamental explanations to them. ii) Tests in thermo-hydraulic (TH) cells that simulate the conditions of the sealing material, providing online measurements of the evolution of e.g. temperature, moisture, suction and pressures. However, the online monitoring of geochemical parameters has proved to be problematic, and hence, the chemical changes and their possible effects on hydro-mechanical properties have to be checked post-mortem. iii) Large-scale tests performed in underground research laboratories. These tests are closely representative of the barrier conditions, but are complicated and expensive and the boundary conditions in them are not always well known. They provide similar online information as the TH cells and rely as well on the post-mortem analyses to assess the chemical changes and interactions. Since these tests are designed to last for long (several years), the post-mortem information available from them is yet limited.

**Marcelo Sanchez**

10:15 AM

Texas A&M University, USA

### “Behavior of Gas Hydrates Bearing Sediments: Geomechanical and Numerical Modeling”

Methane hydrates are ice-like compounds made of gas methane and water. Hydrates are stable under low temperature and high pressure conditions constraining their occurrence in sediments to marine and permafrost settings. A shift from the stability conditions triggers an endothermic hydrate dissociation with the associated release of gas and water, impacting (amongst others) on sediment pore pressure, temperature, and deformations. Therefore, the behavior of hydrate bearing sediments (HBS) is controlled by strongly coupled thermo-hydro-chemo-mechanical (THCM) actions. The analysis of available data from past field and laboratory experiments, and the optimization of future field production studies require a formal and robust numerical framework able to capture the complex behavior of this type of soil. The lecture presents different problems involving HBS, from laboratory experiments involving natural hydrate samples to gas production tests. A comprehensive and fully coupled THCM framework to tackle problems involving HBS is briefly described. The analyses show the complexity of the THCM phenomena associated with this type of system and assist to gain a better understanding on HBS behavior.

# Friday - September 28

9<sup>th</sup> SESSION

11:15 - 12:30 AM

## 9.A Technical Session: Room 3

### Geotechnics for Offshore Energy Applications

- L. Thorel Effect of the soil undrained cohesion profile on the response of a sliding subsea foundation : centrifuge tests
- M. Mehravar Geotechnical Performance of Suction Caisson Installation in Multi-layered Seabed Profiles
- W. Zhou Dynamic responses of jacket foundation offshore wind turbine considering the cyclic loading effects
- H. Wang Comparison of monotonic and cyclic lateral response between monopod and tripod bucket foundations in medium dense sand
- K. Faizi Finite element modelling of the performance of hybrid foundation systems for offshore wind turbines

## 9.B Mini-Symposium: Room 4

### Challenges of Gas Production from Hydrate-Bearing Sediments

Organized by S. Dai, Georgia Institute of Technology

- J. Y. Lee Experimental study on sanding and fine migration during gas production from gas hydrate deposits
- H. Iwai A constitutive model for gas hydrate-bearing soils considering hydrate morphology
- Z. Liu The dynamic characteristics of hydrate-bearing sands measured by resonant column under controlled stress and strain
- J. Zhao Enhancing the gas production from depressurized methane hydrate deposits via warm brine injection
- S. Uchida Sand migration analysis in heterogeneous gas hydrate-bearing sediments during depressurization

## 9.C Mini-Symposium: Room 5

### Computational Waste Management in Geomechanics

Organized by T. Nagel and F. Parisio, Helmholtz Centre for Environmental Research – UFZ

- S.V. Churakov Efficient cross-scale modelling of geochemical interactions for nuclear waste geological disposal
- D. Jaeggi Predictive HM-modeling in the heterogeneous Opalinus Clay of the Mont Terri rock laboratory
- J. Rutqvist Long-term modeling of thermo-hydro-mechanical processes of geologic carbon storage
- B. François Hydro-mechanical modelling of the Boom Clay excavation, convergence and contact with concrete lining
- F. Wuttke Modelling EM heating of porous media with lattice element method

# Friday - September

10<sup>th</sup> SESSION

1:45 - 3:00 PM

## 10.A Technical Session : Room 3

### Other Geotechnical Activities Related to the Energy Sector

- T.-P. Tsai Large Diameter Pile Combined with Micropiles to Improve Stabilization of Transmission Tower Foundation
- S.F.I. Al Abdullah Behavior of free and fixed headed piles subjected to lateral soil movement
- I. Mirsayapov Calculation models of bearing capacity and deformation of soil foundations with vertical elements reinforced under regime cyclic loading
- Y. Choi Study on the pavement structure with solar panel
- P. Psarropoulos Designing Onshore and Offshore Energy Projects in Seismic Areas

## 10.B Mini-Symposium : Room 4

### Challenges of Gas Production from Hydrate-Bearing Sediments

Organized by S. Dai, Georgia Institute of Technology

- L. Yanlong Gravel Sizing Criteria for Hydrate Exploitation Wells and Its Application
- T. X. Le Mechanical properties of synthetic methane hydrate-bearing sand
- A. Alavoine Using numerical homogenization to compute the mechanical response of Gas Hydrate Bearing Sediments
- C. Deusner Mechanical behaviour of gas hydrate-bearing sediments: Effects from changing gas hydrate-sediment fabrics and nonhomogeneous gas hydrate distributions
- D. Sheng Effects of hydrate in sediments on sand crushing

## 10.C Mini-Symposium : Room 5

### Current Advances and Challenges Associated with Geological Disposal

Organized by M. V. Villar, CIEMAT; M. Sanchez, Texas A&M University

- B. Pomaro Coupled THM analyses of nuclear waste barriers incorporating different model assumptions
- M.V. Villar Experimental investigation of gas transport in the shaly facies of Opalinus Clay
- A. Madaschi Mechanical anisotropy of Opalinus Clay shale: a multiscale approach
- M. Sanchez THM Modelling of Expansive Clays incorporating Uncertainty Quantification
- S. Sato Measurement of strain of bentonite-sand mixture in suction cycles

# Friday - September

11<sup>th</sup> SESSION

3:00 - 4:15 PM

## 11.A Technical Session : Room 3

### Hydraulic Stimulation

- K. Teeratorn Investigation on the Productivity Behaviour in Deformable Heterogeneous Fractured Reservoirs
- J.C. Choi Prediction of leak-off pressure in Norwegian offshore using NPD database and deep neural network
- V. H. Tran Numerical assessment of the near-well rock matrix permeability gain due to thermal stimulation
- J. Justo Influence of temperature on the fracture toughness of several rocks
- A. Blaisonneau Adapted modelling strategy developed to support EGS deployment

## 11.B Mini-Symposium: Room 4

### Challenges of Gas Production from Hydrate-Bearing Sediments

Organized by S. Dai, Georgia Institute of Technology

- J. Yoneda Gas hydrate reservoir characterization through pressure core analysis
- S. Kimoto Time dependent behavior of CO<sub>2</sub> hydrate-bearing sediments and its modelling by an elasto-viscoplastic model
- K.A. Alshibli Gas driven fracture during gas production using 3D synchrotron computed tomography
- J. Shen A composite constitutive model for methane hydrate-bearing soils using equivalent granular void ratio

## 11.C Mini-Symposium: Room 5

### Current Advances and Challenges Associated with Geological Disposal

Organized by M. V. Villar, CIEMAT; M. Sanchez, Texas A&M Universtiy

- Q. Wang Volume change behaviour of compacted GMZ bentonite upon wetting/drying cycles
- P. Braun A laboratory testing procedure for the determination of coupled thermo-poromechanical properties of low permeable geomaterials
- S. B. Giger Reconciling static and dynamic elastic properties of Opalinus Clay at multiple scales
- E. Crisci Anisotropic behaviour of shallow Opalinus Clay
- P. Baryla The influence of the different hydro-mechanical paths on final macroscopic properties and local homogeneity of compacted MX80 bentonite samples

# Friday - September 28

## Closing Lecture

4:45 PM

**Paul Bossart**

Swisstopo, Switzerland

**“The international Mont Terri rock laboratory: research in the field of radioactive waste disposal and CO<sub>2</sub> sequestration”**

Rock laboratories are considered as research platforms to carry out experiments, develop new technologies, and demonstrate activities in support of the development of deep geological repositories for disposal of radioactive waste and/or CO<sub>2</sub>. The Mont Terri rock laboratory is just such a facility. The laboratory is located in an extended section of the security gallery of the Mont Terri motorway tunnel, close to the town of St-Ursanne in Canton Jura, Switzerland. The main objective of the research of the 16 partners is the hydrogeological, geochemical and rock mechanical characterisation of the Opalinus Clay, an over-consolidated claystone of Lower Jurassic age. The test results over the last 20 years show that the Opalinus Clay is capable of confining radioactive substances over very long times and isolating them from the biosphere. In recent years, we have adapted and transferred the techniques, measurement methods, and expertise that were developed in the field of radioactive waste disposal to CO<sub>2</sub> sequestration experiments, mainly in the field of wellbore and caprock integrity in claystones.

There are 3 major topics to improve the knowledge of the evolution of a potential repository in the Opalinus Clay:

- 1) understanding the characteristics, processes, and mechanisms in undisturbed clays before construction,
- 2) understanding the repository-induced perturbations during and after construction, and
- 3) conducting experiments related to the demonstration of repository implementation technology.-

We also present experiments in the field of CO<sub>2</sub> sequestration focused on wellbore- and fault integrity and borehole sealants in the Opalinus Clay caprock. This latter is especially important considering that CO<sub>2</sub> stored in a lower aquifer could migrate along artificial and natural flow paths through an upper lying caprock.

The Mont Terri rock laboratory is an essential element in the dissemination of information and improving communication among implementers, safety authorities, and regulators. Based on feedback by visitors, we also address the question of whether rock laboratories increase the public acceptance of radioactive waste disposal and CO<sub>2</sub> storage.



# Lecturers

## J. Carlos Santamarina



### Fractured rock in energy geotechnics

Prof. J. Carlos Santamarina (Professor – KAUST) graduated from the Universidad Nacional de Córdoba, and completed graduate studies at the University of Maryland and Purdue University. Before KAUST, he taught at NYU-Polytechnic, the University of Waterloo (Canada), and Georgia Tech. His former students are academicians, researchers, or practicing engineers at leading institutions around the world. The team's research results are summarized in two books and more than 300 publications. Dr. Santamarina is a member of the Argentinean National Academies (Sciences and Engineering), a recipient of two ASTM Hogentogler Awards, was the 2012 British Geotechnical Association Touring Lecturer, and delivered the 50th Terzaghi Lecture in 2014.

## Fleur Loveridge



### COST GABI Lecture: Urban heat storage using structure and infrastructure foundations

Dr. Fleur Loveridge is a Royal Academy of Engineering Research Fellow and University Academic Fellow based at the University of Leeds. Her research focuses on two main topics: (i) storage of thermal energy in the ground, especially using novel ground heat exchangers such as structure and infrastructure foundations; (ii) the resilience of transport infrastructure, especially earthworks. She is task force leader for ISSMGE TC308 on energy geostructures and storage of thermal energy in the ground, working group leader for energy efficiency for the EU COST Action GABI on Geothermal energy Applications in Buildings and Infrastructure, and was one of the authors of the UK Ground Source Heat Pump Association Thermal Pile Standard. Prior to returning to academia at the University of Southampton in 2009, Fleur spent almost a decade as a consulting engineering in engineering geology and geotechnical engineering working on a range of innovative infrastructure and development projects throughout the world. She is a Chartered Engineer and a Chartered Geologist

## Jonny Rutqvist



### Fault activation, seismicity and leakage in geologic CO2 sequestration

Dr. Jonny Rutqvist is a Senior Scientist at the Lawrence Berkeley National Laboratory, Berkeley, California. His research is focused on modeling of geomechanics as well as coupled thermal, hydraulic, mechanical and chemical (THMC) processes in geological media for a wide range of geoscientific and geoenvironmental applications, including geologic carbon sequestration, geothermal energy extraction, gas hydrate production, underground compressed air energy storage, nuclear waste disposal, and shale gas extraction. Dr. Rutqvist has co-authored over 500 technical publications on the subject, including over 180 peer-reviewed journal papers and book chapters. He is the original developer of the TOUGH-FLAC simulator, which has turned out to be a very versatile tool for modeling coupled multiphase fluid flow and geomechanics. Using TOUGH-FLAC, he was one of the pioneers applying coupled fluid flow and geomechanical modeling to geologic carbon sequestration, such as at the In Salah CO2 storage project, and more recently on the issue of injection-induced seismicity.

## Lyesse Laloui



### **Analysis, Design and Application of Energy Geostrutures from the Building to the City Scale**

Dr. Lyesse Laloui is chaired professor and Director of the Soil Mechanics Laboratory at the Swiss Federal Institute of Technology, EPFL, Lausanne, where he developed a major research group in the areas of Soil Mechanics, Geoengineering and CO<sub>2</sub> sequestration. He is also adjunct professor at Duke University, USA, and advisory professor at Hohai University, China. He edited 10 books and published over 300 peer reviewed papers. He is the Editor in Chief of the International journal Geomechanics for Energy and the Environment. He is the recipient of the “Excellent Contributions Award” of the International Association for Computer Methods and Advances in Geomechanics, the “2012 Vardoulakis Lecture” from the University of Minnesota, the “12th G.A. Leonards Lecture” from the University of Purdue and the “2016 RM Quigley Award” from the Canadian Geotechnical Society. He has been involved as an expert in several international projects and acts as a consultant in civil, geotechnical and geothermal engineering, including legal and arbitration cases. The patented “Geosynthetic element for soil bio-improvement” is currently being developed in the context of a start-up.

## Sébastien J. Burlon



### **GABI: a common European initiative for Geothermal Applications for Buildings and Infrastructure**

Dr. Sébastien Burlon, is currently working in the French company Setec-Terrasol. Civil engineer graduated from École Nationale des Travaux Publics de l'État (ENTPE, Lyon, France) in 2003, he obtained a PhD in Civil Engineering from Lille University in 2007 and an HDR (Accreditation to Direct Research) from Paris-Est University in 2016. During the last 15 years, mainly for IFSTTAR (The French Institute of Science and Technology for Transport, Development and Networks), as geotechnical engineer and researcher, he has been involved in many expertises, research projects and standardization projects (Eurocode 7) dealing with soil-structure interactions and numerical modelling. He is the Chair of the COST Action TU1405 GABI (Geothermal Applications for Buildings and Infrastructure) with 25 European countries involved: the main objective of this Action is to build a new European network of researchers and engineers to address the challenges of thermoactive geostructures in terms of thermal and mechanical design.

## Jean Desroches



### **Hydraulic fracturing, more than a reservoir stimulation technique: from measuring stresses to mine preconditioning**

Jean Desroches has worked on various aspects of hydraulic fracturing since 1985, starting with using tiltmeters to monitor the extent of hydraulic fractures, especially in geothermal environments. He has been working for Schlumberger since 1990, and has held various R&D positions in the UK, the US and France. He has been developing hydraulic fracturing combined with packer fracturing for measuring earth stresses in wellbores, as well as heading efforts to model the various processes associated with hydraulic fracturing as a reservoir stimulation technique. He has directed engineering for well integrity as well as for CO<sub>2</sub> storage. More recently, he has been involved in methods to better take into account rock mechanics information – from rock fabric to geological structure to tectonics – for completing hydraulically fractured wells in complex settings. Jean has coauthored more than 50 scientific publications and 8 patents. He holds a degree in Geological Engineering from École Nationale Supérieure de Géologie, Nancy (France) and a PhD in Rock Mechanics from Institut de Physique du Globe de Paris.

## Stefan Wiemer



### Tailor-made risk governance for induced seismicity of geothermal energy projects

Prof. Dr. Stefan Wiemer is the chair of seismology at the department of Earth Sciences, ETH Zurich, and the director of the Swiss Seismological Service (SED, [www.seismo.ethz.ch](http://www.seismo.ethz.ch)). Born in 1967 in Germany, he graduated from the Ruhr University in Bochum in 1992 and earned his PhD in geophysics from the University of Alaska in Fairbanks in 1996. In 1997, he was awarded a fellowship by the German Alexander von Humboldt Foundation and moved to Tsukuba, Japan. In 1999, he progressed to the SED as a research associate, where he initiated and led research groups on statistical seismology and induced seismicity. He was promoted to titular professor in 2007 and appointed as a full professor and SED director in 2013. His expertise and research interests include probabilistic seismic hazard and risk assessment, time-dependent processes, earthquake predictability and operational earthquake forecasting, earthquake early warning and induced seismicity related to GeoEnergy applications. He published more than 132 articles in international peer reviewed journals since 1994 and supervised 16 PhD students at ETH.

## Marie Violay



### Coupled Hydro-mechanical processes in fault zones, implications for deep geothermal reservoirs

Prof. Marie Violay has been working as an assistant professor at EPF (CH)L since July 2015. She obtained her PhD in 2011 from the University of Montpellier (Fr), under the supervision of Dr. Pezard and Dr. Gibert, working on petrophysical properties of basalt with implications for deep geothermal energy. She served as a post-doctoral research associate at INGV (It) between 2011 and 2013 under the supervision of Prof. Di Toro. Then, she moved to ETHz (CH), and worked as senior scientist in collaboration with Prof. Burg between 2013 and 2015. Her research aims at better understanding the role of fluids on the mechanics of the Earth's crust, especially ruptures. She is interested in developing inter-disciplinary approaches that combine 1) rock mechanics, 2) micro-structural/geochemical investigations, and 3) borehole geophysical observations to study earthquakes, and geological reservoirs. Marie Violay is currently an ERC starting Investigator in mechanical BEhavior of Fluid Induced Earthquake (BEFINE) at EPFL.

## Antonio Gens



### Underground research laboratories in nuclear waste containment

Antonio Gens is professor of Geotechnical Engineering at the Technical University of Catalonia in Barcelona where he has been Head of the Department of Geotechnical Engineering and Geosciences and member of the Governing Council of the University. He has been involved in geotechnical research, consulting and education for more than 30 years and he is the author or co-author of more than 300 scientific papers. He has received numerous awards such as the ICE Telford Medal (twice), the George Stephenson Medal (twice) and the Honour Medal of the Institution of Civil Engineers in Spain. In 2007, he delivered the 47th Rankine Lecture. He is a Fellow of the UK Royal Academy of Engineering and Doctor Honoris Causa by the University of Grenoble. He was Vice-President for Europe of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) for the period 2013-2017. The ISSMGE awarded him the Kevin Nash Gold Medal in 2017.

## Maria Victoria Villar



### Hydro-chemo-mechanical interactions in compacted bentonite

María Victoria Villar has a Ph.D. in Geology and is working since 1989 at CIEMAT, a Spanish research centre for energy, environment and technology. She is an experimentalist, currently head of the Soil Mechanics Laboratory and of the research group on Thermo-hydro-mechanics and geochemistry of geomaterials. Her work has focused on the characterization and assessment of behaviour of host rocks and barrier materials for the disposal of radioactive waste and has been carried out mainly in the framework of projects financed by the European Commission and by Enresa, the Spanish agency for nuclear waste management.

## Marcelo Sanchez



### Behavior of Gas Hydrates Bearing Sediments: Geomechanical and Numerical Modeling

Dr. Marcelo Sanchez is a Professor in the Zachry Department of Civil Engineering TAMU. He obtained his first degree in Civil Engineering from the Universidad Nacional de San Juan (Argentina). His Master and Ph.D. (2004) degrees are from the Universidad Politecnica de Catalunya (UPC, Barcelona, Spain). His expertise lies in the analysis of Thermo-Hydro-Mechanical and Chemical (THMC) coupled problems in geological media and unsaturated soil mechanics. The main applications of his research are related to Energy Geotechnics, Environmental Geotechnics and Transportation Geotechnics. He has published more than 100 peer review papers. He is acting as an Associated Editor of six International Journals. He is one of the recipients of the "George Stephenson Medal 2012" (ICE, UK), and other awards. He is the Chairman of the ISSMGE Technical Committee TC308 on "Energy Geotechnics". More info about Dr. Sanchez' activities can be found at <http://ceprofs.civil.tamu.edu/msanchez/>.

## Paul Bossart



### The international Mont Terri rock laboratory: research in the field of radioactive waste disposal and CO2 sequestration

Paul Bossart works for the Swiss Geological Survey at swisstopo, as director of the international Mont Terri rock laboratory. He received his Ph.D at the ETH Zürich in 1986 (tectonic structure of the Hazara-Kashmir Syntaxis in Northern Pakistan), and holds an MBA of the University of St.Gallen (2004). He was and is involved in several research projects in rock laboratories, such as the Grimsel Test Site (Switzerland), Aespoe (Sweden), Kamaishi (Japan), and the Mont Terri rock laboratory ([www.mont-terri.ch](http://www.mont-terri.ch)).

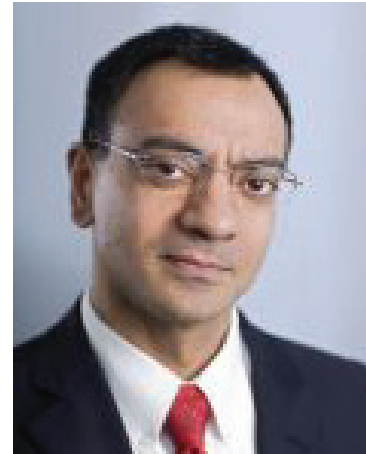
# Innovation Hub

A platform to bring practitioners, engineers, researchers and technology or service providers together to foster the debate around building the sustainable infrastructure systems and technology of tomorrow.

## Experts on our roundtable:



**Andrea Crottini**  
EPFL Technology  
Transfer and  
Intellectual Property  
Manager



**Anil Sethi**  
ETH Zurich Chair of  
Entrepreneurship

## Contributors:



Terralog Technologies Inc.



# Monday - September 24

**COST Action TU 1405 – GABI Short Course** 9:00 AM – 6:00 PM

## How to plan a successful thermoactive geostructure design?

S. Burlon, Terrasol-Setec, France

F. Loveridge, Leeds University, UK

A. Michopoulos, Cyprus University of Technology, Cyprus

D. Pahud, School of Management and Engineering Vaud, Switzerland

A.F. Rotta Loria, EPFL, Switzerland

Despite the significant number of operating energy geostructures in Europe, the development of specific design rules and dimensioning approaches has been slow. Attempts to provide a set of recommendations for piles, diaphragm walls and tunnels subjected to temperature variations were carried out starting from 2005 in Switzerland, Germany, United Kingdom and France. However, most of this documentation provides only general indications and does not allow the adoption of this technology across Europe for a wider range of projects.

This short course organised the COST ACTION TU1405 GABI (Geothermal Applications for building and infrastructures) under the auspices of EPFL aims to synthesize research and practice-based knowledge from across national and disciplinary boundaries in order develop better understanding and more widespread use of this technology.

A certificate of attendance will be delivered at the end of the course.

9:00	Registration - Welcome
'30	Introduction - Main steps for the design of a thermoactive geostructure -S. Burlon
10:00	Legal issues Building energy demand Heat pumps
'30	A. Michopoulos
11:00	Coffee break
'30	How to measure THM ground properties (laboratory and in situ tests)?
12:00	A.F. Rotta Loria, S. Burlon & F. Loveridge
'30	
13:00	Lunch
'30	
14:00	Thermal design (energy piles and tdiaphragm walls)
'30	D. Pahud
15:00	Coffee break
'30	Mechanical design (energy piles, diaphragm wall and tunnels)
16:00	A.F. Rotta Loria & S. Burlon
'30	
17:00	Execution and Monitoring S. Burlon & F. Loveridge
'30	
18:00	Discussions - Conclusions

# Saturday - September 29

## Mont-Terri Underground Rock Laboratory Visit

7:15AM - 4:30 PM

Just after the symposium (on the 29th of September 2018) there will be a visit to the Mont-Terri Underground Rock Laboratory, located in the canton of Jura, 300 m underground. Numerous experiments are carried out here on the Opalinus Clay, which is, among other things, a potential host rock for future nuclear waste storage activities in Switzerland.

The tour will then begin with a short presentation and discussion about the work being performed at Mont-Terri. After the discussion, we will tour the actual facilities and visitors will be able to see how many of the experiments are being performed. Finally, we will have an apéro at the visitors centre in the early afternoon before returning back to EPFL.

During and before the visit the SEG2018 hotline will be active (tel: +41 079 5702114) for any information or support.

### MEETING POINT

Laboratory of Soil Mechanics  
Entrance GC D, Chemin du barrage

### VISIT SCHEDULE

- 7:15 Meeting of the participants
- 7:30 Bus departure
- 10:00 Visit of the Underground Rock Laboratory
- 13:00 Apéro at the Mont - Terri visitors centre
- 14:00 Departure from Mont - Terri



# Total final energy consumption in Switzerland in 2016 with shares of renewable energy

Final energy consumption 2016:  
854'300 TJ

# 22.1%

Renewable energy  
Final consumption

# 13.4%

Electricity

# 4.62%

Wood

# 1.86%

Ambient heat

# 0.89%

District heating

# 0.27%

Share of renewable  
energy from waste

# 0.32%

Gas

# 0.29%

Solar power

# 0.42%

Liquid biogenic  
vehicle fuels

# 77.9%

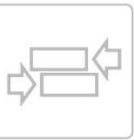
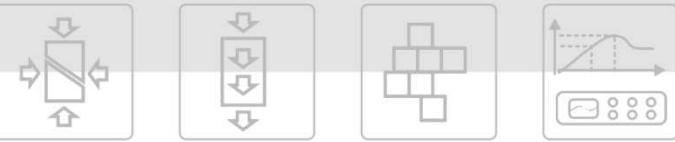
Final consumption of  
non-renewable energy



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Static and dynamic ring shear apparatus

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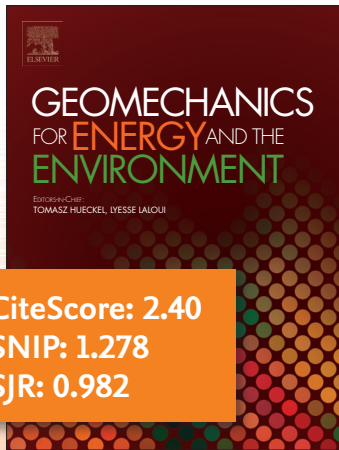
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**FLOATING SOLAR PARK PROJECT, MOORED STRUCTURE AT THE SHORES OF THE LAKE  
LAC DES TOULES (VS), PHOTOMONTAGE**



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