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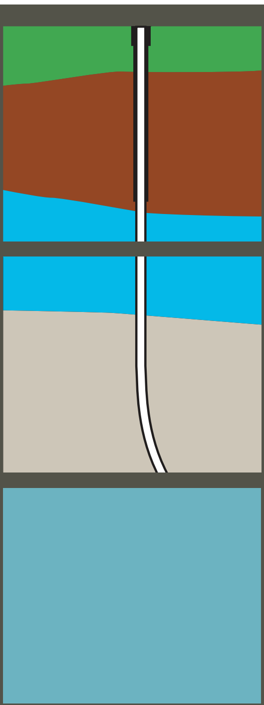
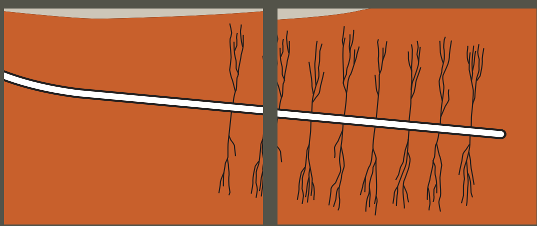


# Gas Shales

## Opportunities, Challenges and Achievements



ACTUEL

ÉNERGIE LE DÉBAT RESTE OUVERT

GAZ DE SCHISTE: LE FEU AU LAC N'EST PAS POUR TOUT DE SUITE

- «EFFICIENCE 21», Automne 2013

**Les gaz non conventionnels font peur. Quels risques comportent les forages? Où en est-on en Suisse? Le point avec le professeur Lyesse Laloui, directeur du Laboratoire de mécanique des sols à l'EPFL et Jean-Yves Pidoux, conseiller municipal Vert et directeur des Services industriels de Lausanne...**

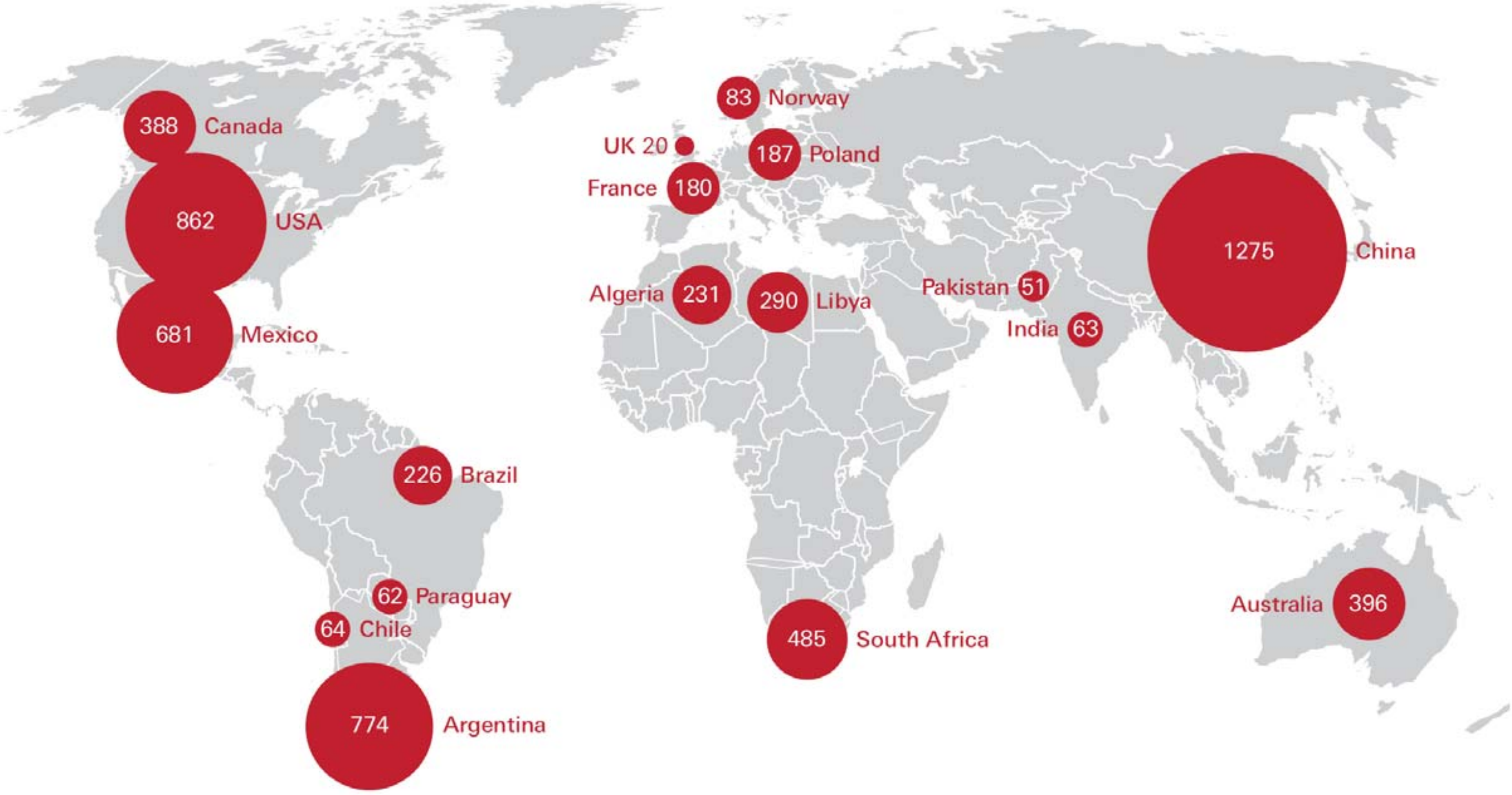
**Geomechanics: a one-way road toward a safer, more efficient and conscious shale gas exploitation.**

Shales are extremely complex geomaterial and many challenges are associated to the shale gas extraction and production. As a consequence geomechanics is the "pass" to achieve a better understanding and a deeper knowledge of shales behaviour when subjected to engineering practices such as drilling and fracturing.

- What we know: shale gas as a promising global energy resource for the future.
- What we need to know: the scientific challenges.
- What we do: scientific bases for a competent exploitation.

# GAS SHALE: A Promising Energy Resource for the Future

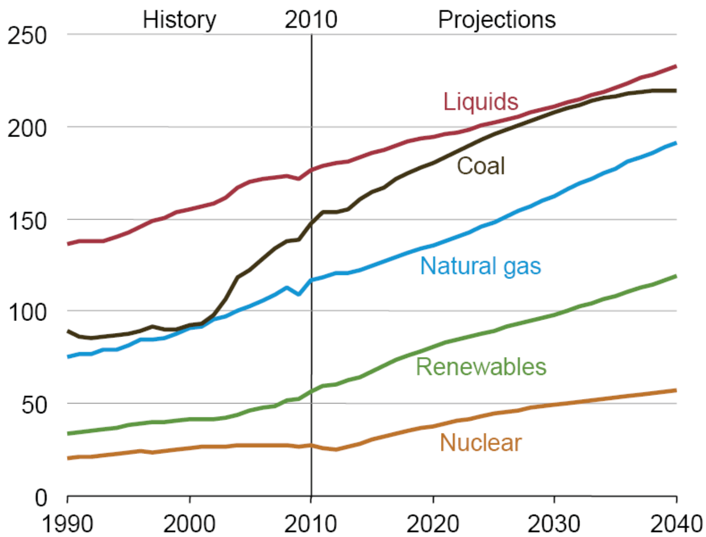
Estimates of technically recoverable shale gas resources (trillion cubic feet, tcf) based on 48 major shale formations in 32 countries - *EIA, 2011*




## Overview

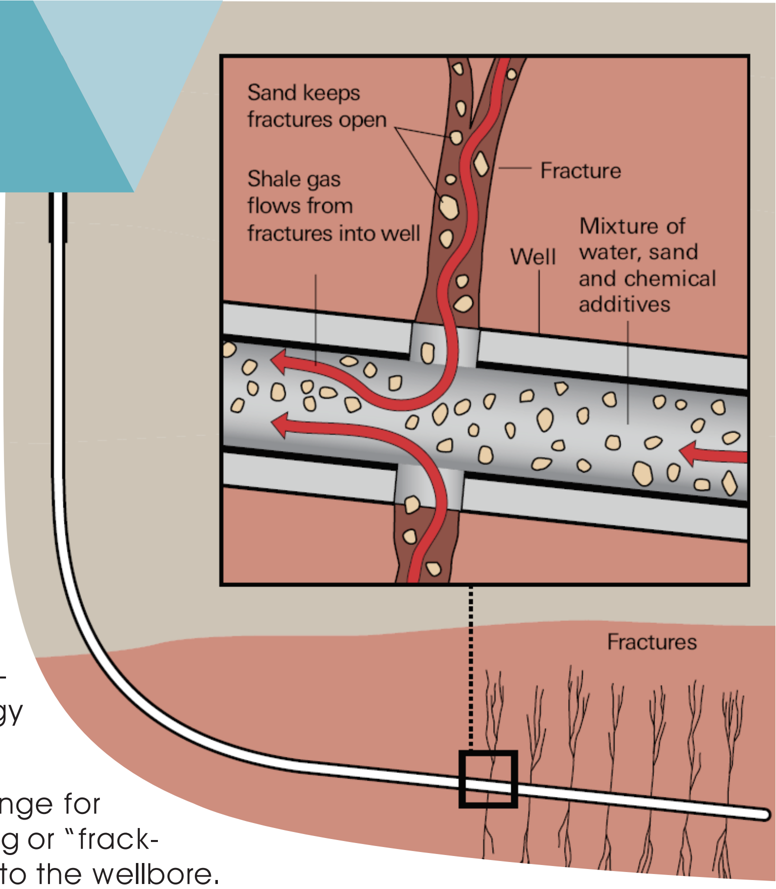
Growing interest toward shale gas for the future global energy supply is nowadays observed. The US Energy Information Administration (EIA) estimates that the world energy consumption of natural gas will observe a great and rapid increase in the next decades. This increases highlights of the need to look for new gas resources to compensate such demand.

The EIA has identified a number of plays across Europe where organic-rich shales are present. Poland and France are two of the most promising shale gas countries with respectively 5.3 trillions of $m^3$ and 5 trillions of $m^3$ of technically recoverable resources. With great shale gas potentials are also present in the South of England, France, Northern Germany, the Netherlands, and **Switzerland**.




World energy consumption by fuel type, 1990-2040 (quadrillion Btu) - *EIA, 2013*

# GAS SHALE: Scientific Challenges




An illustration of hydraulic fracturing (Al Granberg/ ProPublica). Fracturing fluids are injected under pressure to stimulate fractures in the shale. The fractures are propped open by sand contained in the fracturing fluid so that shale gas can flow out of the shale into the well. - *The Royal Society and The Royal Academy of Engineering, 2012*

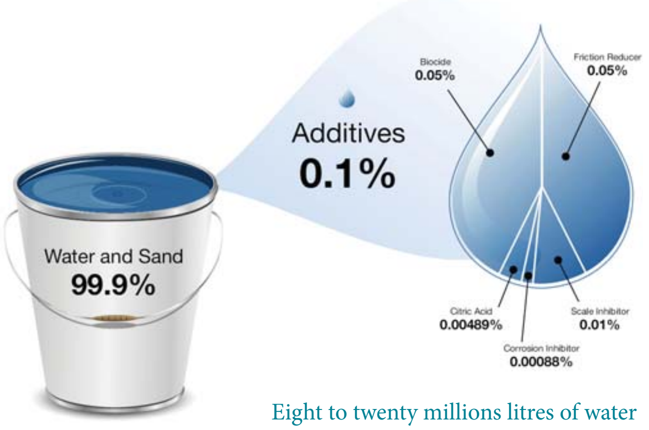
## Fracking & Extraction

The increasing interest on gas shales comes along with several concerns about the reliability, affordability and security of this unconventional energy source.

The very low permeability of the shales is a challenge for the shale gas extraction thus the hydraulic fracturing or "fracking" is performed in order to expose more surface to the wellbore. First of all, explosive charges are fired in order to create holes along the well in pre-defined positions within the shale formation (production zone). Subsequently, the injection of fracturing fluids under high pressure into the well is carried out generating the hydraulic fractures or causing the expansion and propagation of the existing fractures. In this way the gas production is enhanced and the extraction rate is increased.

Along with the issues related to fracking, the extraction of the shale gas from such low porosity and permeability media encounters a number of additional scientific and technological challenges:

- Drilling
- Wellbore stability
- Hydraulic fracturing or "fracking"
- Drilling and fracturing fluids chemical composition
- Amount of proppant to be used
- Drilling and fracturing fluids chemical interaction with the shale
- Fracture propagation control
- Fracture water/gas conductivity
- Thermal gradient between injected fluids and shale formation
- Induced seismicity



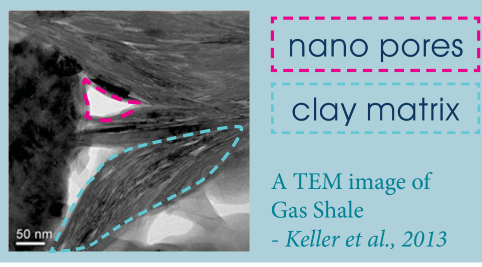

Eight to twenty millions litres of water may be necessary to fracture one horizontal well in shale formations. *- Report by Government of New Brunswick, Canada*

## WHAT ARE SHALES ?

Shales are fine-grained, sedimentary geomaterials composed of clay minerals and tiny fragments (silt-sized particles) of other minerals, especially quartz and calcite.

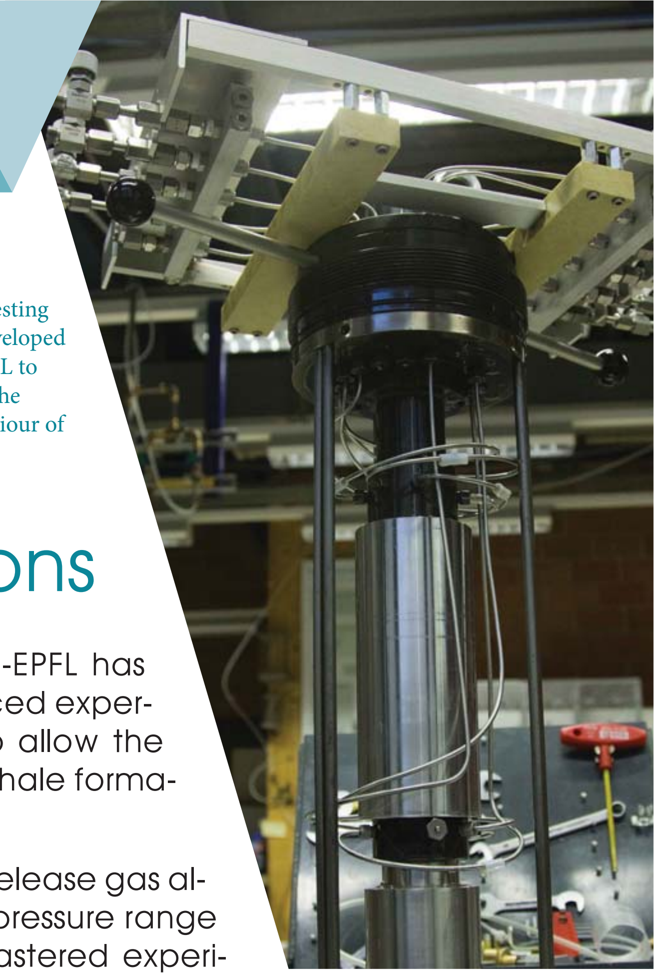
### MAIN CHARACTERISTICS

Low porosity: 10 -15 %
Low permeability: 1 – 1'000 nD
High stiffness: 1 – 10 GPa
Pore size: dozens of nm




A TEM image of Gas Shale *- Keller et al., 2013*

# GAS SHALE: Our Expertise & Competence



Advanced testing facilities developed at LMS-EPFL to investigate the THM behaviour of shales.

## Testing in extreme conditions

For proper and safe shale gas exploitation, the LMS-EPFL has established a comprehensive research asset: advanced experimental tools and models have been developed to allow the reproduction of the extreme in situ conditions of the shale formation in terms of pressures, temperature and chemistry.

Testing the ability of the material to retain water and release gas allows the identification of the gas entry pressure and pressure range involved in the gas extraction. The LMS-EPFL has mastered experience in providing such information through the study of the water retention properties of shales.

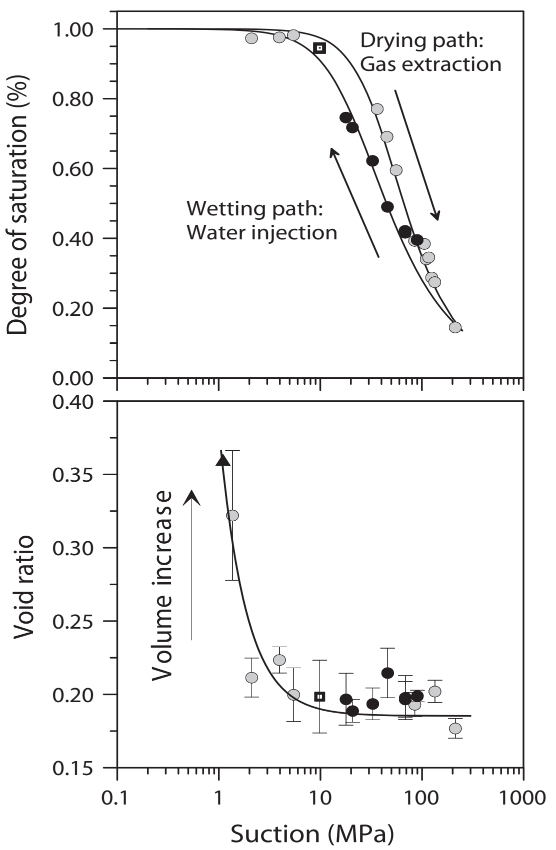
T: 20-150°C

H: -400-20MPa

M: 0-230MPa

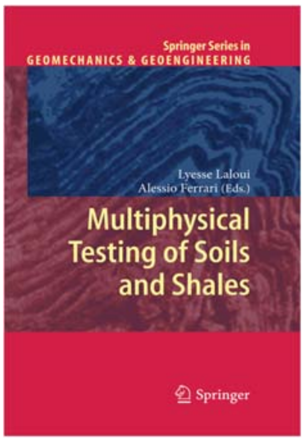
C: 2-12PH

At the depths of shale gas reservoirs, where high temperatures are involved, the drilling and fracturing operations can cause the development of thermal gradients and simultaneous changes in the degree of saturation. Temperature and degree of saturation affect the stress state. As a consequence it is fundamental to analyse the geomechanical response of the material under a variety of coupled thermo-hydro-mechanical conditions. An advanced high pressure-high temperature oedometric cell and a thermo-hydro-mechanical THM triaxial system are used at LMS-EPFL to provide a comprehensible and robust description of the material behaviour at high temperatures and pressures either in saturated or unsaturated conditions.



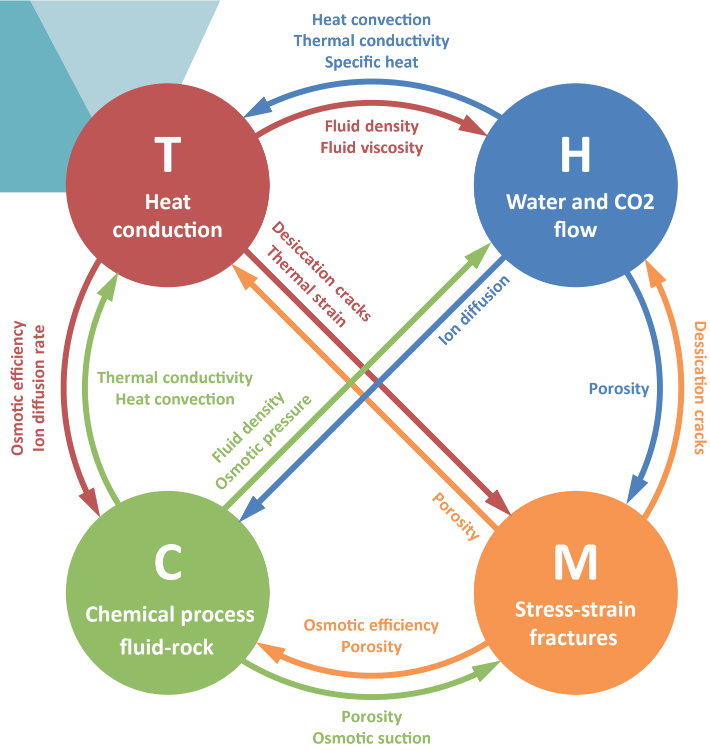

Relationship between the degree of water saturation and the negative pore water pressure (suction) for a Swiss shale and investigated along wetting and drying paths. Wetting and drying cycles are well representative of the water injection during the hydraulic fracturing and gas extraction stages.

Porosity variation due to changes in suction or degree of saturation in the shale matrix: water injection and gas extraction can significantly influence the porosity of the material. - *Ferrari and Laloui, 2012*




Multiphysical Testing of Soils and Shales (2013) by Prof. Lyesse Laloui and Dr. Alessio Ferrari.

# GAS SHALE: Our Expertise & Competence

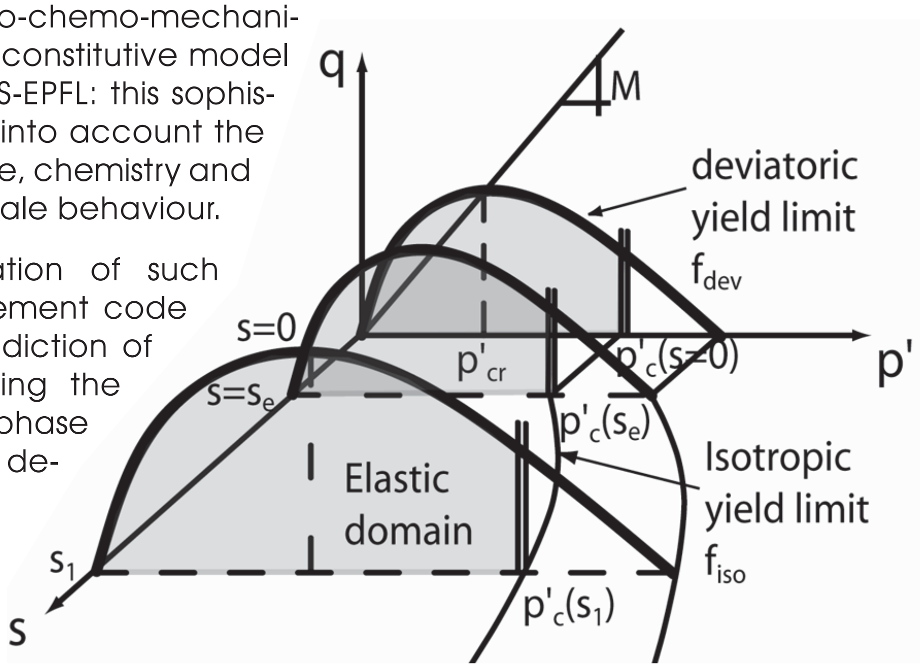



Thermo-hydro-chemo-mechanical coupled processes during gas extraction from and injection into natural reservoirs.

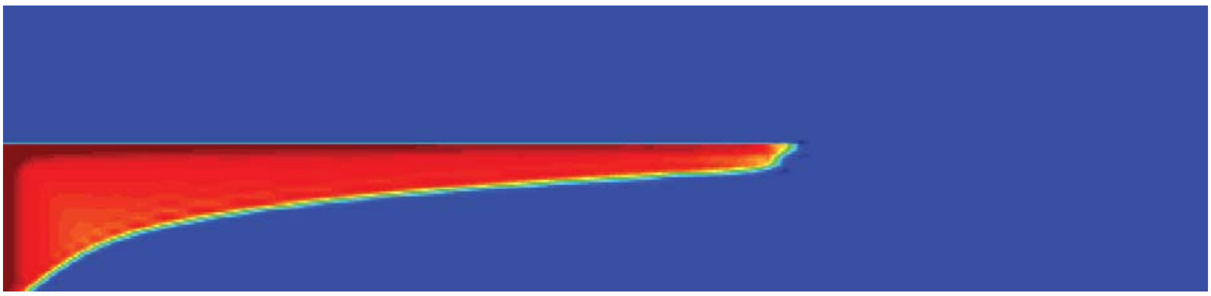
## Development & Prediction

The comprehensive experimental campaign on the geomechanical behaviour of shales constitutes the base for the development of a theoretical and constitutive modelling framework to successfully describe and predict the response of shales when they are subjected to various thermo-hydro-chemo-mechanical conditions. An advanced constitutive model (ACMEG) is developed at LMS-EPFL: this sophisticated model is able to take into account the coupled effects of temperature, chemistry and degree of saturation on the shale behaviour.

The subsequent implementation of such powerful model in a finite element code allows the simulation and prediction of fluid-rock interactions, including the opportunity to deal with multiphase multicomponent fluid flow in deformable porous media.




Effect of suction variation (or degree of saturation variation) on the material yield limit according to the ACMEG model - *François and Laloui, 2008*



Simulation of $CO_2$ injection through a vertical well into a water saturated reservoir (2kmx200m). The $CO_2$ is trapped well by the merely imperious shale. Due to the difference in density between water and $CO_2$, leading to the buoyancy effect, a plume-like shape of $CO_2$ saturation profile is formed. - *Li and Laloui, 2013*

# GAS SHALE: Our Industrial Partners

LMS-EPFL is participating in the prestigious SHARC Consortium. It is a joint industry project that aims at improving the understanding of shale behaviour. Research projects have been also established with industrial partners which are leaders in the field of shale gas exploitation.


References

EIA, World shale gas resources: an initial assessment of 14 regions outside the USA, US Energy Information Administration, Department of Energy: Washington DC. http://www.eia.gov/. (2011)

EIA, World Energy Outlook 2013. US Energy Information Administration, Office of Energy Analysis, Department of Energy, Washington, DC. http://www.eia.gov/. (2013)

The Royal Society and The Royal Academy of Engineering. Shale gas extraction in the UK: a review of hydraulic fracturing. Report. (2012)

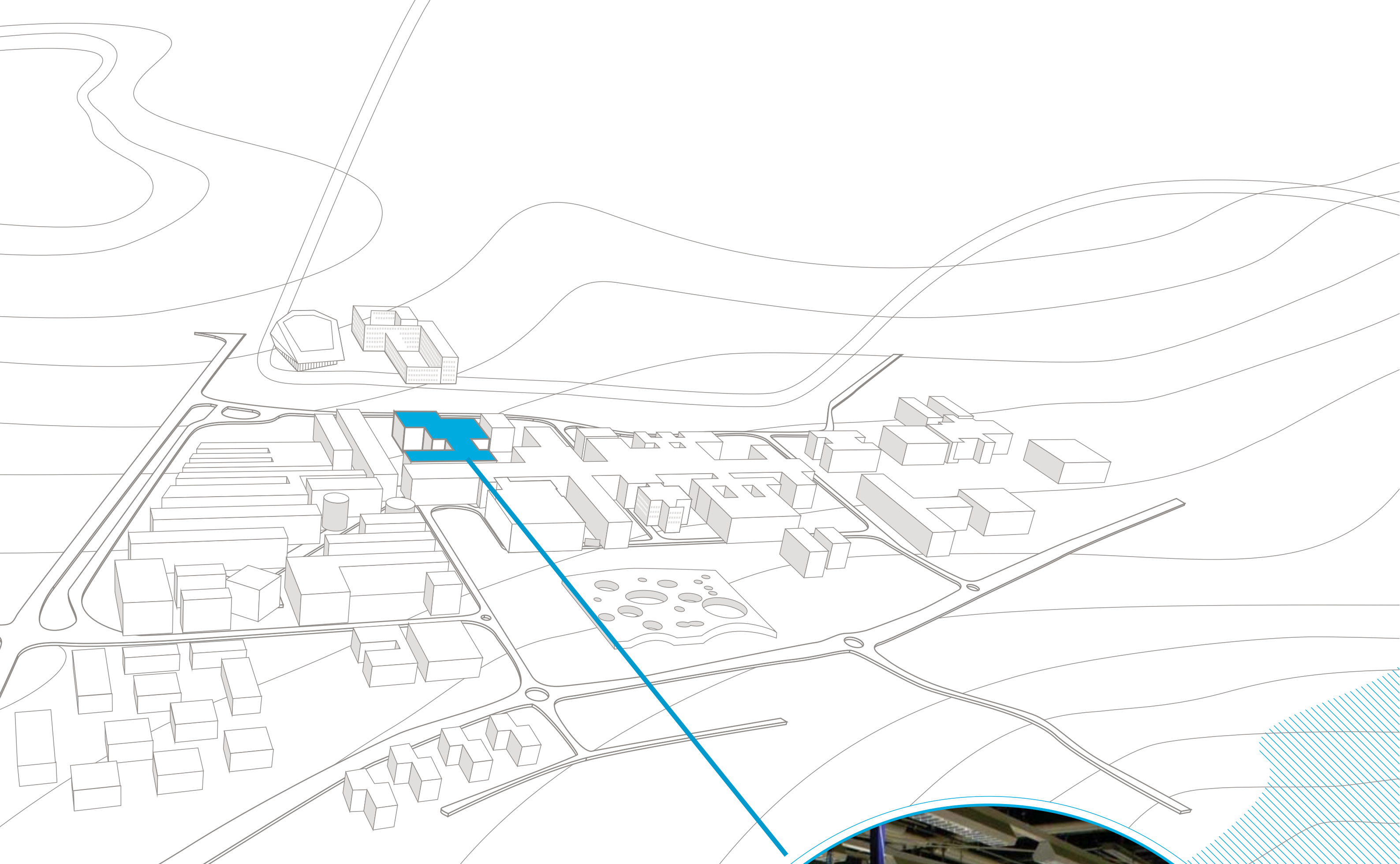
Government of New Brunswick, Canada. Drilling and Completing Shale Gas Wells. http://www2.gnb.ca/.

Lukas M. Keller, Philipp Schuetz, Rolf Erni, Marta D. Rossell, Falk Lucas, Philippe Gasser, Lorenz Holzer: Characterization of multi-scale microstructural features in Opalinus Clay. Microporous and Mesoporous Materials, 170, 83–94. (2013)

Ferrari A. and Laloui L.: “Advances in the testing of the hydro-mechanical behaviour of shales”. In L. Laloui and A. Ferrari editors. Multiphysical Testing of  Soils and Shales, pages 57-68, Springer, (2012)

François, B. and Laloui, L.: ACMEG-TS: A constitutive model for unsaturated soils under non-isothermal conditions. International Journal of Numerical and Analytical Methods in Geomechanics, vol. 32, p. 1955–1988 (2008)

Li C. and Laloui L., Pressure management in a CO2 reservoir and its impact on mechanical stability(submitted). International Journal for Numerical and Analytical Methods in Geomechanics 2013.



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