# Technical Workshop (day 1)

## "The long-term fate of $CO_2$ during geological storage"

Wednesday, October, 28, 2015

**Venue: Amphithéâtre Sequoia, IFPEN, Rueil Malmaison, France**

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| **08.30 – 09:00** | **Welcome coffee** | *Pascal Audigane (BRGM)*<br>*Nicolas Maurand (IFPEN)* |
| **09.00 – 09:30** | **Introduction**<br>• Introduction to the workshop, ULTimateCO2 project<br>• "Long term" in the CCS Directive | *Pascal Audigane (BRGM)* |
| **9:30-12:00** | **Session: CONFORMITY WITH MODELING PREDICTIONS** | *Chairs / Speakers* |
| **9:30-9:40**<br>10 mn Talk | **Introduction to the session** | *Nicolas Maurand (IFPEN)*<br>*Pascal Audigane (BRGM)* |
| **9:40-10:00**<br>15 mn Talk<br>5 mn Discussion | **Paris basin: from geological restoration to $CO_2$ injection with dynamic meshing**<br>• A 3D modeling of basin-scale restoration: application to the Paris Basin<br>• A construction of initial boundary conditions for pressure, temperature and salinity field | *Nicolas Maurand (IFPEN)* |
| **10:00-10:20** | **Long-term trapping mechanisms - the GeoLorraine case**<br>• Influence of the stochastic geological realizations upon the long-term trapping at the regional scale using the Lorraine geological context, France | *Yann Le Gallo (GEOGREEN)* |
| *10.20 – 10:50* | *Coffee Break* | |
| **10:50 – 11:10** | **The Aquistore project**<br>• An update on the Aquistore project: $CO_2$ storage in deep saline aquifer, Petroleum Research Council, Canada. | *Kyle Worth (PTRC)* |
| **11:10 – 11:20** | **Upscaling –modelling of dissolution reservoir trapping**<br>• Modeling of the convective flow of the native brines in a saline aquifer containing dissolved $CO_2$<br>• How to upscale such process when considering reservoir or basin scale models with marge grid element | *Nicolas Maurand (IFP)*<br>*Peter Frykman (GEUS) Yann Le Gallo (GEOGREEN)* |

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| **11:20 – 11:40** | **Influence of subseismic blind faults - the GeoLorraine case**<br>• Modelling of faults between storage and control aquifers<br>• Coupled flow and geomechanical behavior to investigate the $CO_2$ migration during $CO_2$ injection | *Yann Le Gallo (GEOGREEN)* |
| **11:40 – 12:00** | **Panel discussion: Recommendations on CONFORMITY** | *Chair + AB + Audience* |
| *12.00 – 13:30* | *Lunch* | |

**Afternoon session**

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| **13:30 – 16:30** | **Session2: ABSENCE OF ANY DETECTABLE LEAKAGE** | *Chairs / Speakers* |
| **13:30 – 13:40** | **Introduction to the session** | *Jan Heege (TNO)*<br>*Pascal Audigane (BRGM)* |
| **13:40 – 14:00** | **Mechanical and transport properties of gouge-bearing faults in clay-rich caprocks: short- and long-term aspects.**<br>• Mechanical and permeability tests performed on simulated clay-rich fault gouges<br>• Geochemical and microphysical modelling<br>• Short term experiments show that clay-rich, gouge-bearing faults exhibit stable (aseismic) slip behavior when (re-) activated<br>• Transient permeability decreases with increasing fault displacement (maturity) and with increasing clay content<br>• Geochemical modelling of long term fluid-rock interaction shows that the composition of typical clay-rich fault rocks does not change significantly with time | *Elisenda Bakker,*<br>*Sabine den Hartog*<br>*Christopher Spiers (UU)* |
| **14:00 – 14:20** | **Transport processes in fractured formations - what can we learn from natural analogues?**<br>• The transport of $CO_2$ through fractured caprocks and aquifers is a function of the connectivity of the fracture network and the hydraulic properties of the fractures, especially aperture and surface roughness. Field and lab work on a natural analogue site in Southern Germany revealed some of the main hydrogeological features of fractured systems but also the remaining challenges and limitations. | *Georg Houben (BGR)* |
| **14:20 – 14:40** | **Modelling of the CO2-induced degradation of a fractured caprock during leakage: potential for a mechanical self-limiting process**<br>• Investigation of the potential for limitation of the leakage via initiation of ductile deformation leading to reduced permeability;<br>• Numerical coupled transport-chemical simulations were set up using the Opalinus clay formation as an analogue for a caprock layer;<br>• The damage zone of the fractured system becomes more collapsible over time, which eventually leads to initiation of ductile deformation onset given low-to-moderate pressure build-up. | *Jeremy Rohmer, (BRGM)*<br>*Joachim Tremosa,*<br>*Nicolas Marty,*<br>*Pascal Audigane* |

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| *14:40 – 15:00* | *Coffee Break* | |
| **15:00 – 15:20** | **Understanding the evolution of a well's integrity during its lifetime: outcomes of the Mont Terri well experiment**<br>• A new 1:1-scale experiment has been proposed for observing and understanding the evolution of in-situ well integrity due to changes that could occur during a well's lifetime, including contact with $CO_2$. The results include a 2.5 year-long hydraulic and geochemical monitoring of the system under different physico-chemical conditions, and an observation of the system after its overcoring. | *Jean Charles Manceau (BRGM)*<br>*Joachim Tremosa (BRGM)*<br>*Christophe Nussbaum (SWISSTOPO)* |
| **15:20 – 15:40** | **Geochemical reactivity of Opalinus Clay (OPC) & Class G cement**<br>• $CO_2$/Brine/OPC interactions<br>• $CO_2$/Brine/Cement interactions<br>• Conditions 20 bar/30°C (Mont Terri URL exp.) & 100 bar/40°C (shallow reservoir) | *Olaf Ukelis (EIFER)* |
| **15:40 – 16:00** | **Geochemical aspects of leakage: insights from modelling**<br>• Evaluation of the long term alteration of materials deteriorate by geochemical processes influencing sealing efficiency of pore-scale properties (porosity and permeability) | *Fabrizio Gherardi (CNR-IGG)* |
| **16:00 – 16:20** | **Panel Discussion: Recommendations on LEAKAGE** | *Chair + AB + Audience* |
| *20.00 – 22:00* | *Dinner* | *Restaurant*<br>*Les Noces de Jeannette*<br>*Angle 14 rue Favart - 9, rue d'Amboise 75002 Paris* |

# Technical Workshop (Day 2 morning)

Thursday, October, 29, 2015

**Venue: Amphithéâtre Sequoia, IFPEN, Rueil Malmaison, France**

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| **08.45 – 09:00** | **Welcome** | *Pascal Audigane, BRGM* |
| **09.00 – 11:45** | **Session3: EVOLUTION TOWARDS A SITUATION OF LONG TERM STABILITY** | *Chairs / Speakers* |
| **9:00 – 9:10** | **Introduction to the session** | *Peter Frykman (GEUS)*<br>*Pascal Audigane (BRGM)* |
| **9:10 – 9:30** | **Long-term trapping-time-security diagrams as a thumbnail for site performance**<br>• Based on long-term simulations for 1,000 - 10,000 years, the evolution of the trapping mechanisms and the proportions of each of them over time, is evaluated and discussed | *Peter Frykman (GEUS)* |
| **9:30 – 9:50** | **How can we take uncertainty into account in long-term predictions?**<br>• A methodology is presented to integrate uncertainty assessment when evaluating through numerical modeling the long term effect of $CO_2$ geological storage<br>• Case study are presented: influence of reservoir and fluids properties uncertainty, influence of geochemical kinetics on the dissolution and precipitation of rock minerals, and on the mechanical stability of faulted systems | *Felipe Aguirre (PHIMECA)*<br>*Thierry Yalamas*<br>*Julien Schueller* |
| *9:50 – 10:20* | *Coffee Break* | |
| **10:20 – 10:40** | **Post-injection trapping of mobile CO2 in deep aquifers: assessing the importance of model and parameter uncertainties**<br>• An approach is proposed to assess the importance ranking of uncertainty sources, with regards to the behavior of the mobile CO2 during the post-injection period. The applicability of the approach is tests on the GeoLorraine case | *Jeremy Rohmer (BRGM)*<br>*Jean-Charles Manceau* |
| **10:40 – 11:00** | **Role of Impurities on the long term trapping of CO2**<br>• Presentation of autoclaves experiences of the influence of impurities ($SO_2$, $NO_2$ and $H_2S$) on sandstones mineralogy for short term<br>• Predictions of the long term evolution by numerical modeling | *Keith Bateman (BGS)*<br>*Joachim Tremosa (BRGM)* |
| **11:00 – 11:20** | **Natural analogues to improve our understanding on the long term mineral trapping of CO2**<br>• Long-term CO2-rock interaction in existing natural CO2-rich reservoirs<br>• Rock studied: the Werkendam and Waalwijk natural gas fields in the Netherlands, wells in Gemmingen and Bad Theinach, Germany, natural gas fields in the southern North Sea, UK | *Jeremy Rushton (BGS)*<br>*Georg Houben (BGR)*<br>*Marielle Koenen (TNO)* |

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| | • Collection of petroleum field analogues data and description of risks of CO2 leakage along faults | |
| **11:20 – 11:40** | **Panel Discussion: Recommendations on STABILITY** | *Chair + AB + Audience* |
| **11:40 – 12:00** | **Wrap up session and guidelines report**<br>• Summary of panel sessions<br>• Presentation of the guidelines report | *Pascal Audigane (BRGM)*<br>*Helen Taylor (BGS)*<br>*Rowena Stead (BRGM)*<br>*Holger Cremer (TNO)* |
| | **Close of the Workshop** | |
| *12:00 – 13:00* | *Lunch* | |

***** close of meeting *****