
Mechanisms of gas migration in flooding post-mining context
Experimental approach and modelling
MINES ParisTech
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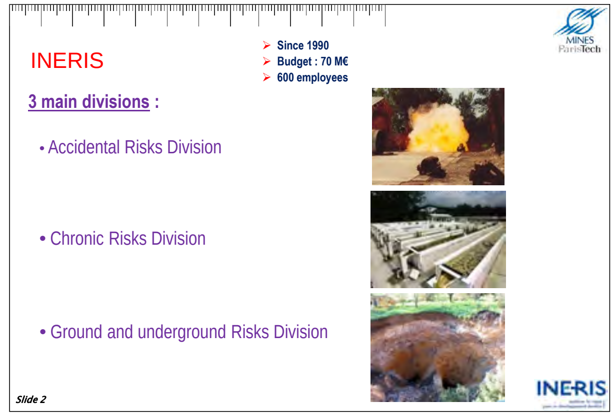
INERIS
IMWA 2010
Mine Water & Innovative Thinking
September 5 - 9, 2010
CAPE BRETON UNIVERSITY


INERIS
Since 1990
Budget : 70 M€
600 employees
3 main divisions :
• Accidental Risks Division
• Chronic Risks Division
• Ground and underground Risks Division
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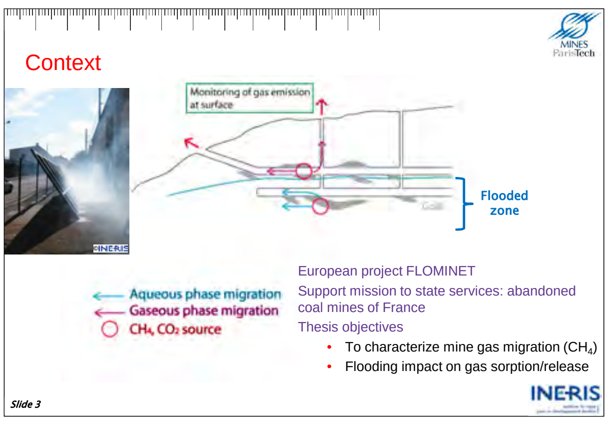
Context
Monitoring of gas emission at surface
Flooded zone
Aqueous phase migration
Gaseous phase migration
CH4, CO2 source
European project FLOMINET
Support mission to state services: abandoned coal mines of France
Thesis objectives
• To characterize mine gas migration (CH4)
• Flooding impact on gas sorption/release
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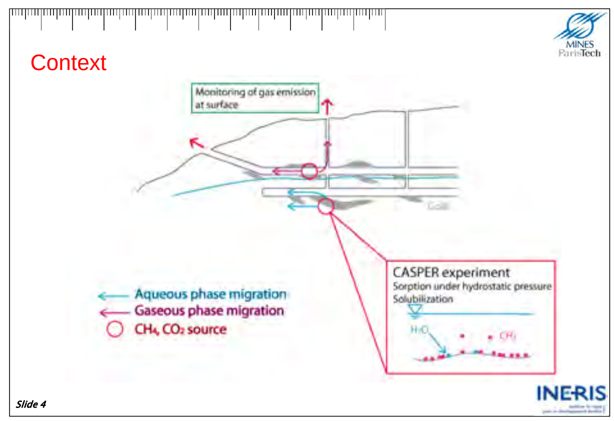
Context
Monitoring of gas emission at surface
CASPER experiment
Sorption under hydrostatic pressure
Solubilization
Aqueous phase migration
Gaseous phase migration
CH4, CO2 source
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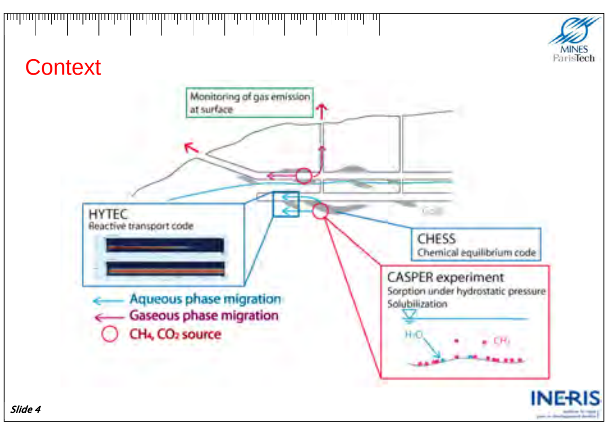
Slide 4


Context
Monitoring of gas emission at surface
HYTEC
Reactive transport code
CHESS
Chemical equilibrium code
CASPER experiment
Sorption under hydrostatic pressure
Solubilization
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Gaseous phase migration
CH4, CO2 source
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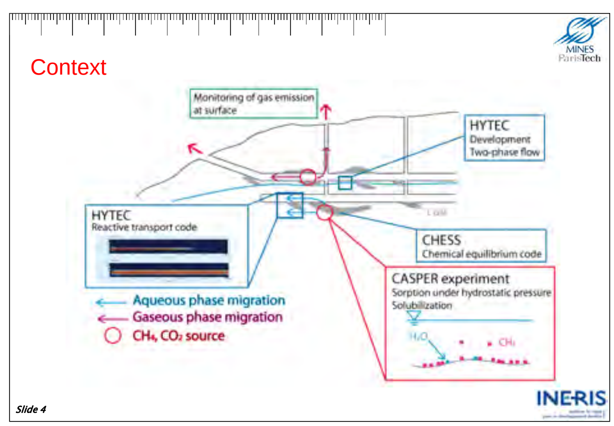
Context
Monitoring of gas emission at surface
HYTEC
Development
Two-phase flow
HYTEC
Reactive transport code
CHESS
Chemical equilibrium code
CASPER experiment
Sorption under hydrostatic pressure
Solubilization
Aqueous phase migration
Gaseous phase migration
CH4, CO2 source
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## Laboratory experiment

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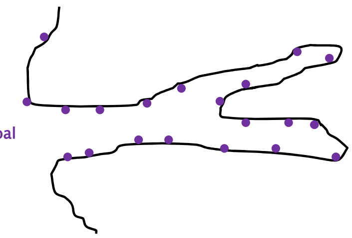
## CASPER : objectives

(sorption capacity under high hydrostatic pressure during rock flooding)

To reproduce flooding conditions

To measure released gas from coal for given hydrostatic pressure

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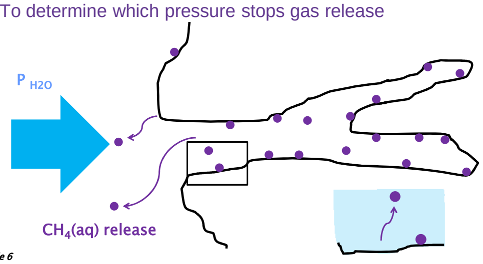
## CASPER : objectives

(sorption capacity under high hydrostatic pressure during rock flooding)

To reproduce flooding conditions

To measure released gas from coal for given hydrostatic pressure

To determine which pressure stops gas release

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## CASPER: initial system

Water pressure: stop gas release, $H_2O/CH_4$ competition on sites ?

Hypotheses:

- Presence of water decreases $CH_4$ sorption (e.g. Joubert et al., 1973 ; Crosdale et al., 2008 ; Charrière, 2009)
- Released $CH_4$ enters aqueous phase, no gas in the cell

First result (quick and dirty)

- Experiment released amount : **0.003** mol (water degassing)
- Validation with solubility model of Duan and Mao (2006)

Gas molar fraction — Chemical potential — Fugacity coefficient — $CH_4$ – cations – anions interactions — Molality

$$\ln\frac{y_{CH_4}P}{m_{CH_4}} = \frac{\mu^{l(0)}_{CH_4}}{RT} - \ln\varphi_{CH_4} + \sum_c 2\lambda_{CH_4-c}m_c + \sum_a 2\lambda_{CH_4-a}m_a + \sum_c\sum_a \xi_{CH_4-c-a}m_c m_a$$

- Soluble amount in the cell : **0.0036** mol

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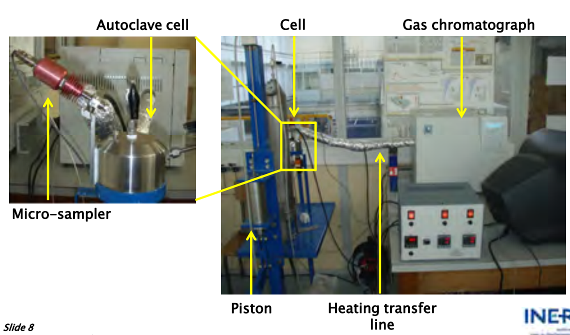
## CASPER

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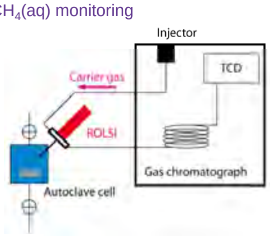
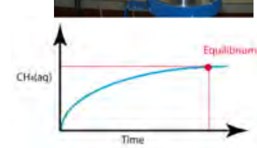
## CASPER: sampling/analysis system

Water with aqueous gas sampling: ROLSI™ (Rapid On Line Sampling Injector)

Analysis : gas chromatograph

$CH_4$(aq) monitoring

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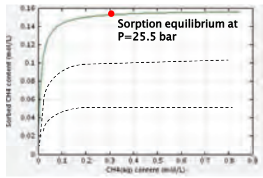
## Experimental result fit

Reproduction of experimental conditions

Defined mineral species ↔ coal

- Sorption sites

CoalSite + $CH_4$(aq) ⇄ CoalSite-$CH_4$




Adsorption constant K

$$K = \frac{[CoalSite-CH_4]}{[CoalSite][CH_4(aq)]} = \frac{[N_{TOT}\,sites]-[CH_4(aq)]}{[CH_4(aq)]^2}$$

- Log (K) = 1.87

(P = 25.5 bar , T = 26°C)

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## Modelling

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## HYTEC

(Hydrological Transport coupled with Equilibrium Chemistry)

Reactive transport

Current code

- Flow, advection, diffusion, dispersion
- Mobile and immobile phases
- Chemical reactions : CHESS

CHESS (Chemical Equilibrium of Species and Surfaces)

- Speciation
- Adsorption
- Chemical equilibrium
- Kinetics

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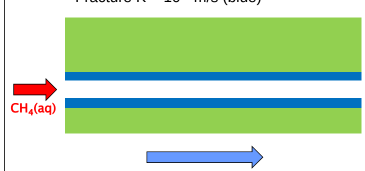
## $CH_4$(aq) migration/adsorption

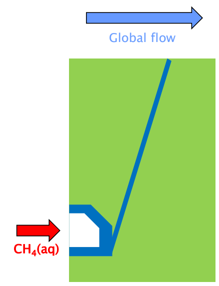
$CH_4$(aq) plume migration

- Gallery K = $10^{-1}$ m/s (white)
- Fractured coalbed K = $10^{-4}$ m/s (blue)
- Fresh rock K = $10^{-6}$ m/s (green)
- Head gradient Δh = 0.01

Impact of fracture

- Fracture K = $10^{-4}$ m/s (blue)

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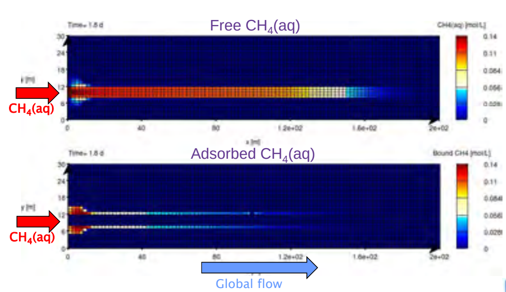
## $CH_4$(aq) migration/adsorption

$CH_4$(aq) plume migration

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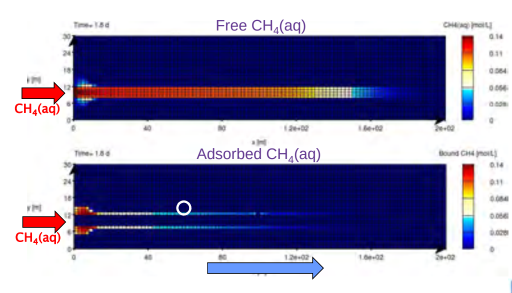
## $CH_4$(aq) migration/adsorption

$CH_4$(aq) plume migration

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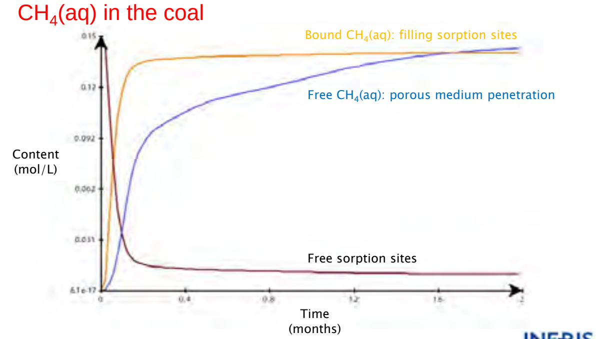
## $CH_4$(aq) in the coal

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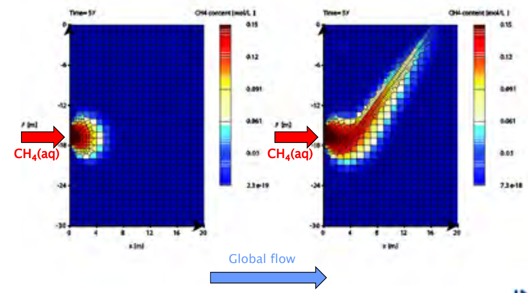
## $CH_4$(aq) migration

Impact gallery/fracture connection

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## Wrapping up & prospects

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## Wrapping up

Several phenomena to take into account

CASPER

- First result consistent with bibliography
- New protocol operational end of summer 2010 : faster, better quality

HYTEC

- Sorption equilibrium constant
- $CH_4$(aq) migration in different structures

## Prospects

Flooding modelling in development (unsaturated flow)

Two-phase flow : end of the year 2010

Development of tools for gas risks management in flooded mines

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*Thank you for attention*

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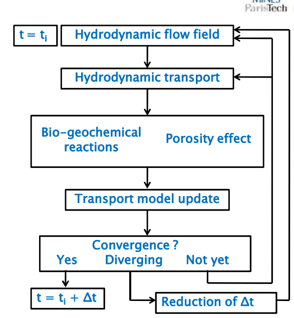
## HYTEC

(Hydrological Transport coupled with Equilibrium Chemistry)

Finite volumes

Voronoï mesh

Discretization : one-step time centered




Source: *van der Lee et al., 2003*, modified

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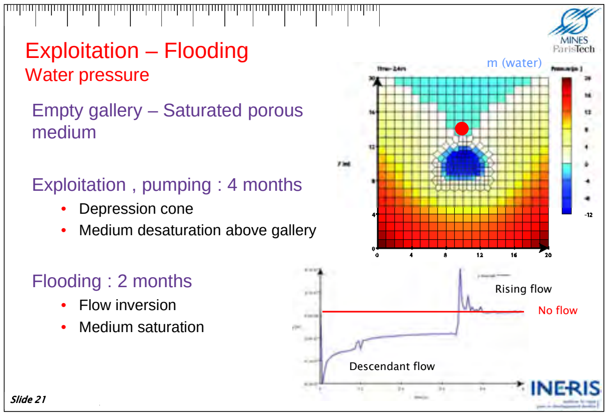
Exploitation – Flooding
Water pressure
Empty gallery – Saturated porous medium
Exploitation , pumping : 4 months
Depression cone
Medium desaturation above gallery
Flooding : 2 months
Flow inversion
Medium saturation
m (water)
Rising flow
No flow
Descendant flow
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