

H-NAT 2023

POTENTIAL • EXPLORATION • PRODUCTION

27 – 28 NOVEMBER 2023 | 3rd edition

1st Natural Hydrogen Worldwide Summit

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27 NOVEMBER 2023

04:20 - 04:40

CONFERENCE TITLE

SysMoG™ probe :
an innovative technology for
the exploration and
monitoring of dissolved
gases at great depth

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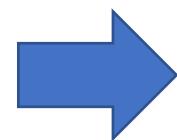
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SysMoG™ a generic probe concept for the analysis of dissolved gases: the result of more than 20 years of fundamental and applied research until the discovery of H₂ in the Lorraine basin (France)

a synthetic summary of the main key stages in the development of the SysMoG™ probe



from 2002 until today.....!

SysMoG



2002

2008

2009

2010

2011

2013

2014

2015

2017

2020

2021

2023

Nuclear waste storage

Greenhouse gas monitoring

Geological storage of CO₂ (CCUS)

Urban waste storage

Hydrogen storage

Low carbon energy

Natural Hydrogen

1) VINSOT A., et al. CO₂ data on gas and pore water sampled in the Opalinus Clay at the Mont Terri rock lab **Physic and Chemistry of the Earth**, 33 554-560 (2008)

2) PIRONON J., et al. On-line greenhouse gas detection from soils and rocks formations - **Energy Procedia**, 1 2375-2382 (2009)

4) GAL F., et al. Surface Gas Geochemistry Above The Natural CO₂ Reservoir Of Montmiral (Drôme-France), Source Tracking And Gas Exchange Between Soil, Biosphere And Atmosphere. - **Oil & Gas Science and Technology Rev.** IFP, 65 635-652, (2010)

5) PIRONON J., et al. On-line greenhouse gas detection from soils and rocks formations - **International Journal of Greenhouse Gas Control**, 4 217-224 (2010)

6) de DONATO Ph., et al. CO₂ flow baseline: key factors of the geochemical monitoring program of future CO₂ storage at Claye-Souilly (Paris basin). - **Energy Procedia**, , 4 , 5438–5446, (2011),

7) CAILTEAU C., et al. FT-IR metrology aspects for on-line monitoring of CO₂ and CH₄ in underground laboratory conditions.. - **Analytical methods**, 3, 877-887, (2011)

8) CAILTEAU C., et al. In situ gas monitoring in clay rocks: Mathematical developments for CO₂ and CH₄ partial pressure determination under non-controlled pressure conditions using FT-IR sensors. - **Analytical methods**, 3, 888-895, (2011)

9) PIRONON J., et al. How to establish CO₂ flow/concentration warning levels based on the geochemical monitoring baseline: specific case of CO₂ storage at Claye-Souilly (Paris basin). - **Energy Procedia**, , 37, 4409-4419, (2013),

10) TAQUET N., et al. Efficiency of combined FTIR and Raman spectrometry for online quantification of soil gases: Application to the monitoring of carbon dioxide storage sites - **International Journal of Greenhouse Gas Control**, 12,359-371 (2013)

12 LABAT N. et al. Carbon Capture and Storage : The Lacq pilot – Chap. VII Environmental monitoring and modelling. - **TOTAL Publisher**, 141-215, (April 2015),

13) VINSOT A., et al. Natural gas extraction and artificial gas injection experiments in Opalinus Clay. **Swiss Journal of Geosciences**, 1-16, (2017).

11) GAL F., et al - Study of the environmental variability of gaseous emanations over CO₂ injection pilot – Application to the French Pyrenean foreland. - **Internal Journal of Greenhouse Gas Control**, 21, 177-190, (2014)

14) LAFORTUNE S., et al - Monitoring of hydrogen leaks from a deep underground storage. Part 1: In situ validation of an experimental protocol via the injection and monitoring of helium and tracers in a shallow aquifer. **Applied Sciences** (2020), Special Issues , 10, 6058-6076, (2020).

15) ADISAPUTRO D., et al - Development and Field Testing of Baseline Subsoil Gas Measurement: An In-situ and Continuous Monitoring Concept for CO₂ and CH₄ in A Forest Ecosystem (Montiers, Lorraine Region, France) - **Applied Sciences** -11, 1753. (2021).

16) GOMBERT P., et al - Monitoring of hydrogen leaks from a deep underground storage. **Applied Sciences** (2021) Special Issues , 11, 2686, (2021).

17) LACROIX E., et al - Metrological development based on in situ and continuous monitoring of dissolved gases in an aquifer: application to the geochemical baseline definition for hydrogen leakage survey. **Analytical Methods**. doi: 10.1039/d1ay01063h (2021)

18) GOMBERT Ph , et al - Advances in Underground Energy Storage for Renewable Energy Sources **Applied Sciences** , ISBN 978-3-0365-1879-4. (2021).

19) LE V.L., et al - Quantitative monitoring of dissolved gases in a flooded borehole: calibration of the analytical tools - **Science and Technology for Energy Transition (STET)**, 78,, (2023)

20) HELMLINGER B., et al - SysMoG™ , Probe for gas analysis in wells at high depth. **European Bureau Patent**, N° EP22210240.2 - Avril 2023 -

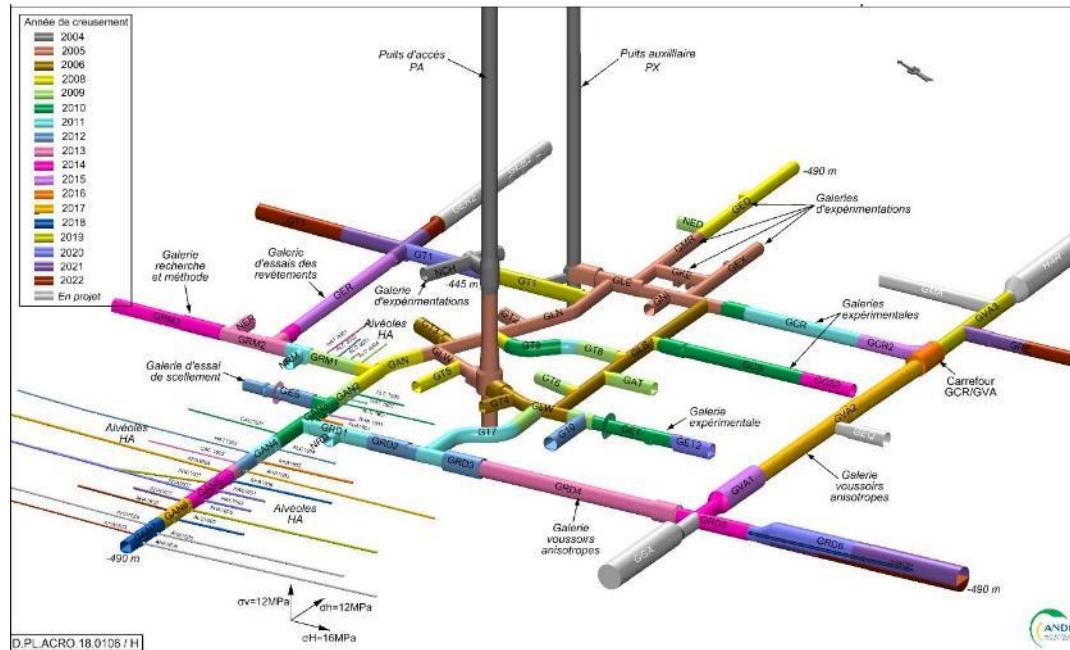
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2005

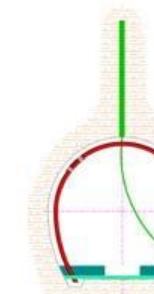
Context: Underground laboratory of Meuse/Haute-Marne (ANDRA) - France

continuous and in-situ monitoring of CO₂ and CH₄ in the clay formation of *Callovo-Oxfordian* at -490 m

Main Galleries of the Bure Laboratory in 2022 (ANDRA)



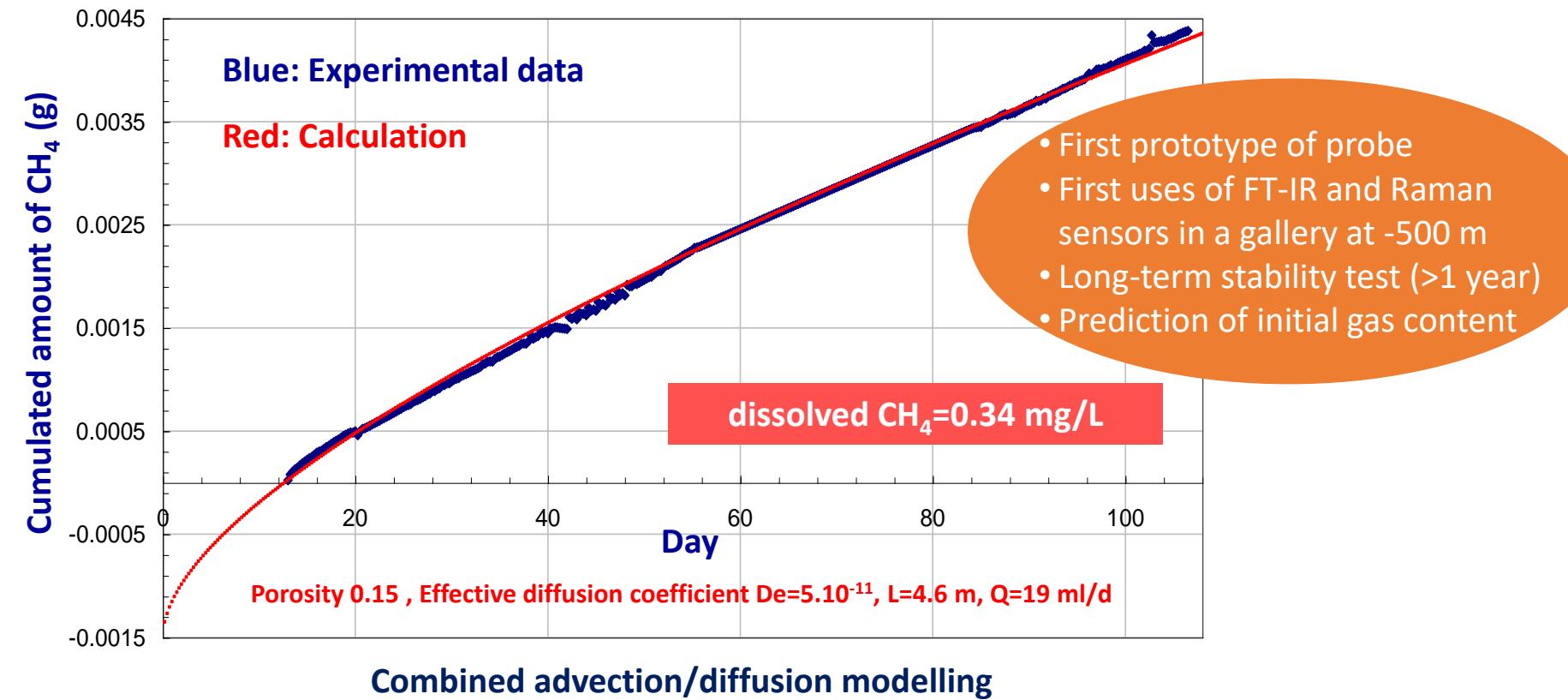
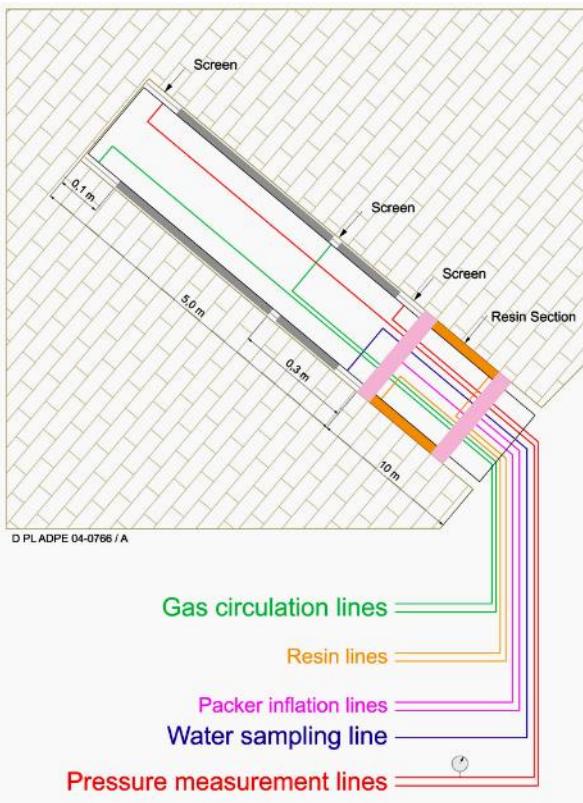
Location in the gallery of the SysMoG™ probe



2005

Context: Underground laboratory of Meuse/Haute-Marne (ANDRA) - France

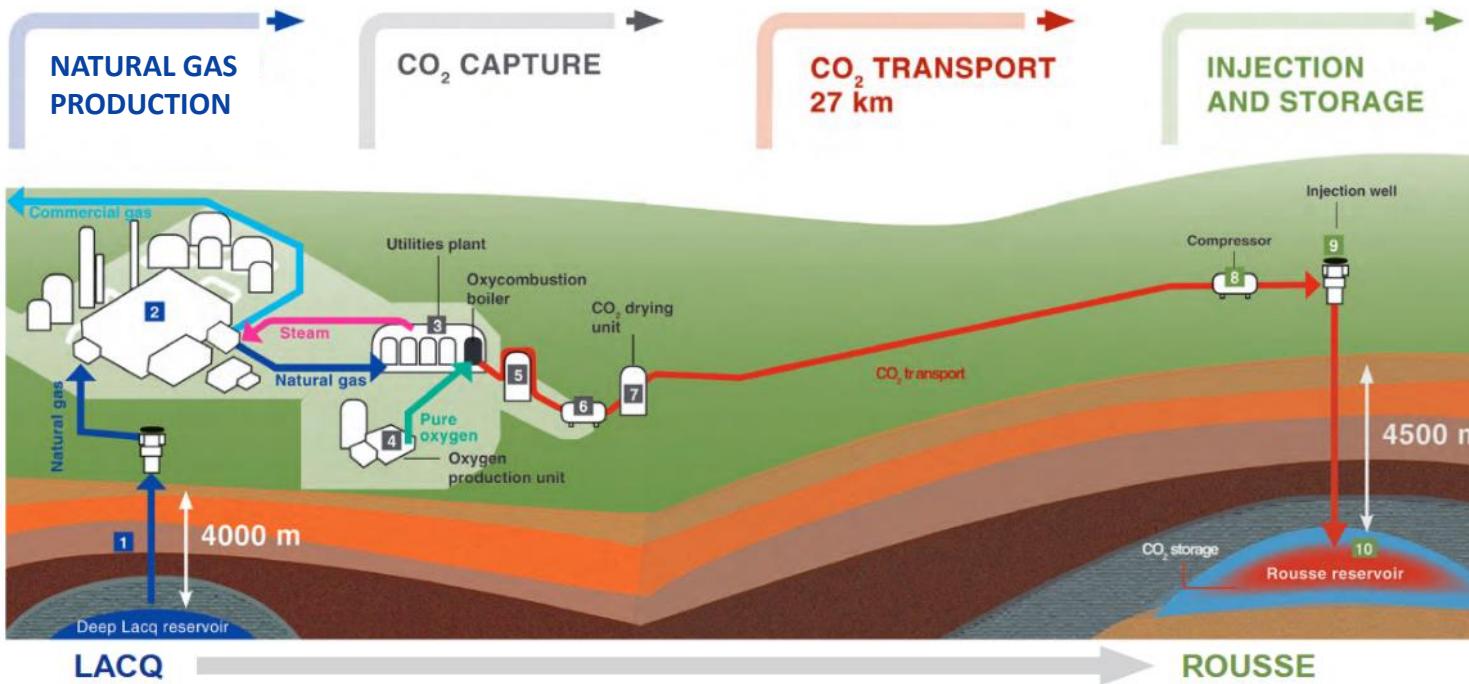
continuous and in-situ monitoring of CO₂ and CH₄ in the clay formation of *Callovo-Oxfordian* at -490 m



2010

Context: Carbon Capture and Storage of CO₂ / The Lacq pilot - France

Surface monitoring of CO₂ storage sites: Flow assessment and source tracing on surface compartments: geosphere/biosphere/atmosphere

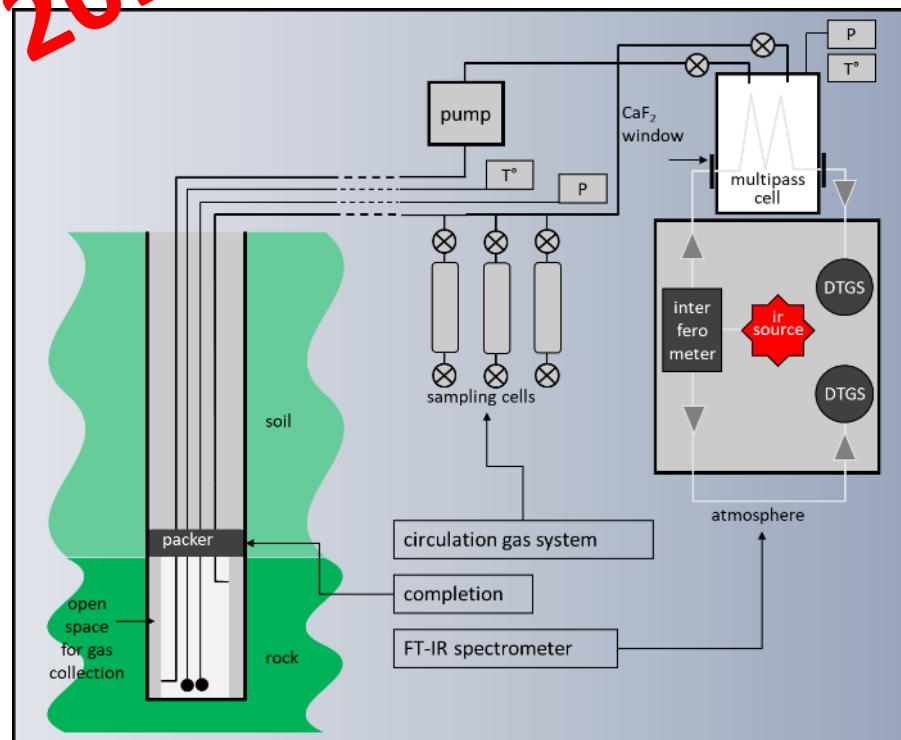


Rousse Site

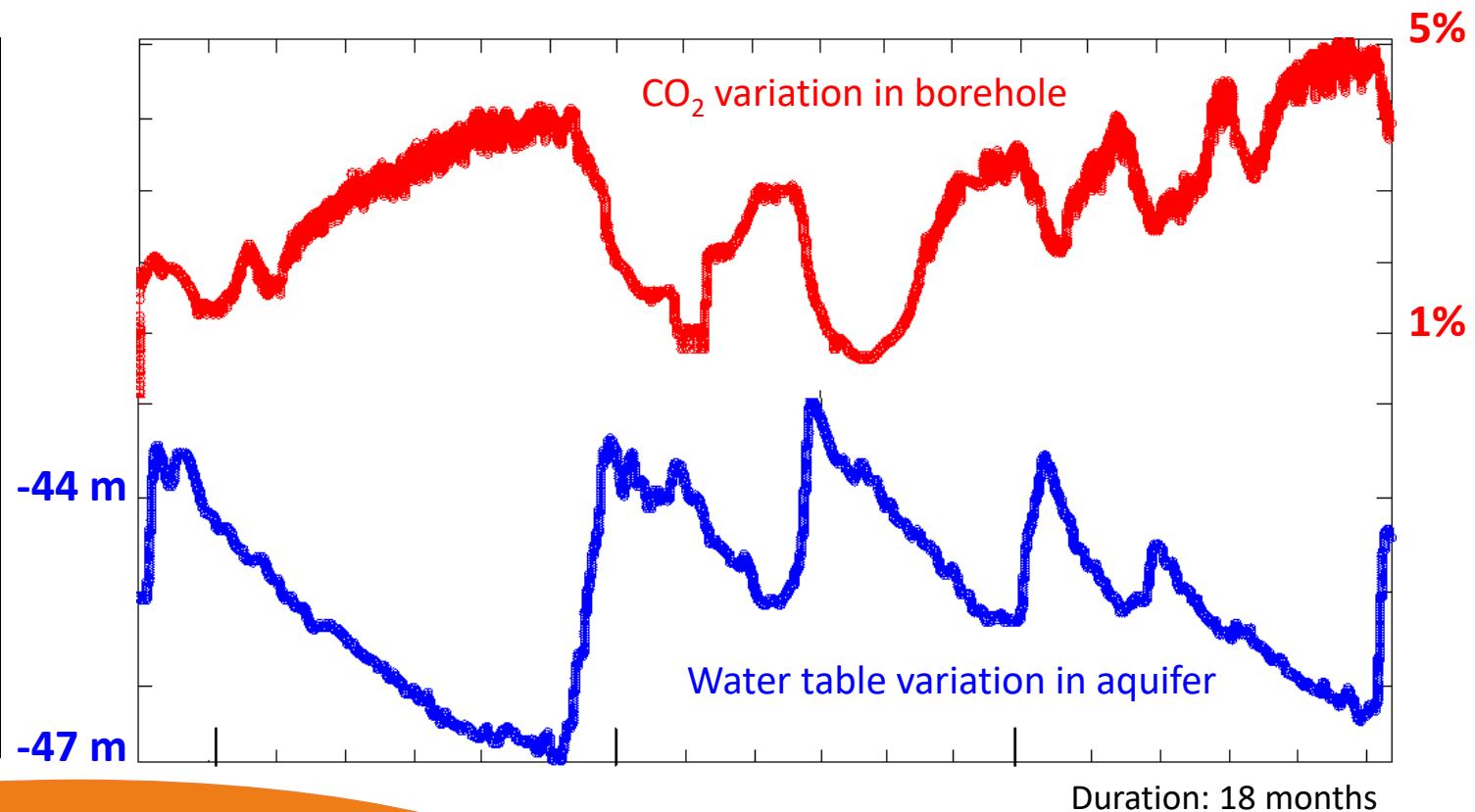


2010

Global view of the SysMoG™ device

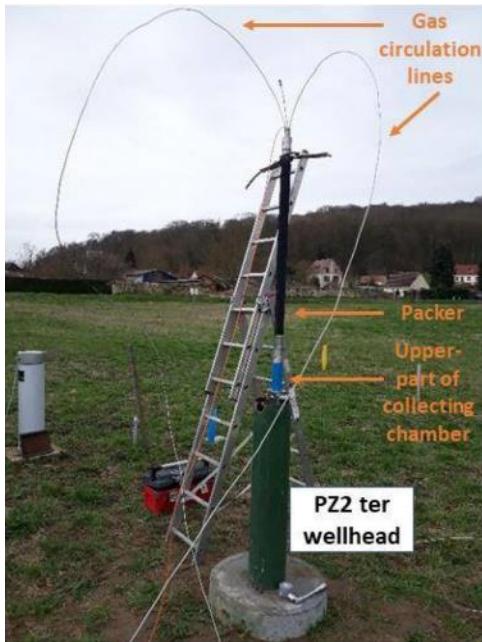


CO₂ concentration in the soil vs. water table



- First remote measurements
- First application of fiber Raman sensor
- CO₂ in soil is governed by water table variations

2020

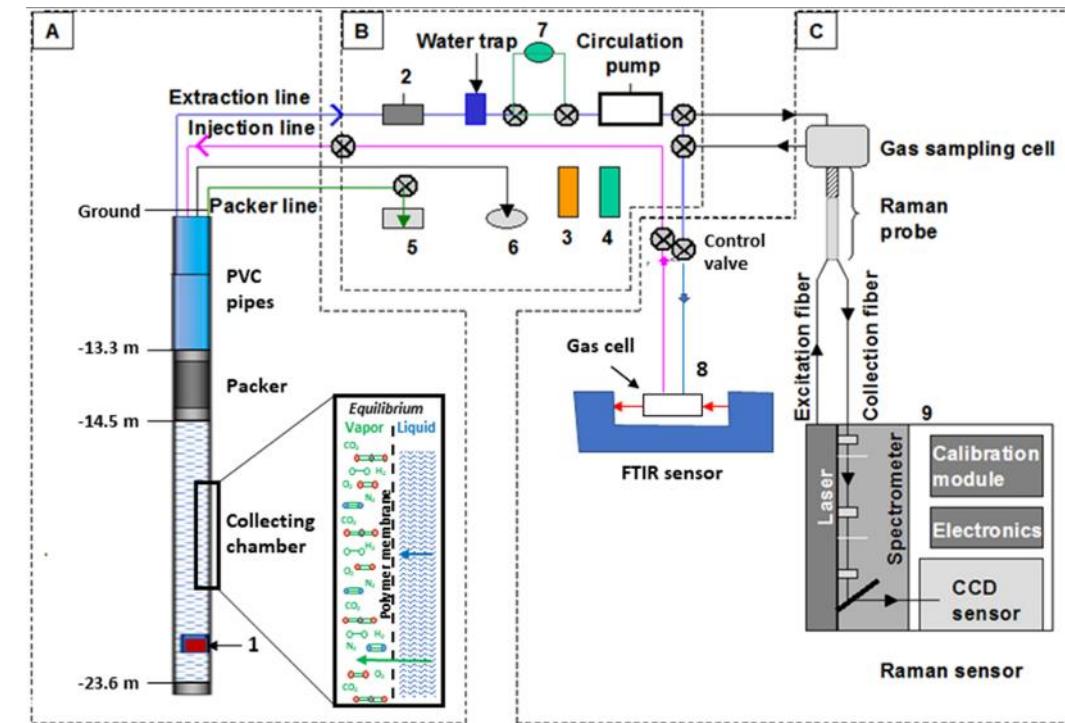
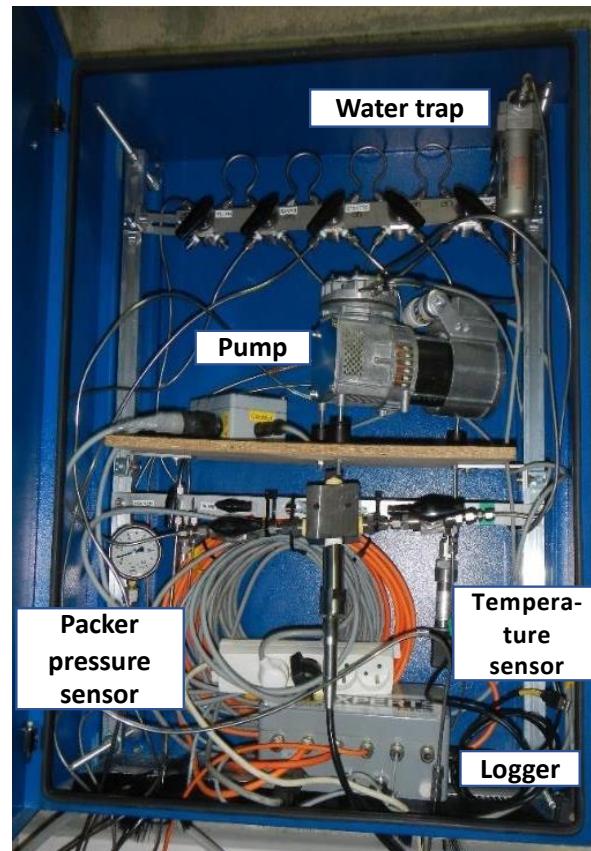


SysMoG™ probe for aquifer monitoring

Context: Hydrogen monitoring in aquifer environment

Experimental site of INERIS (Cattenoy, France)

Risks and Opportunities of geological STORAGE of Hydrogen in salt cavities in France and Europe



Optimization the SysMoG™ device for dissolved gas monitoring

H₂ storage

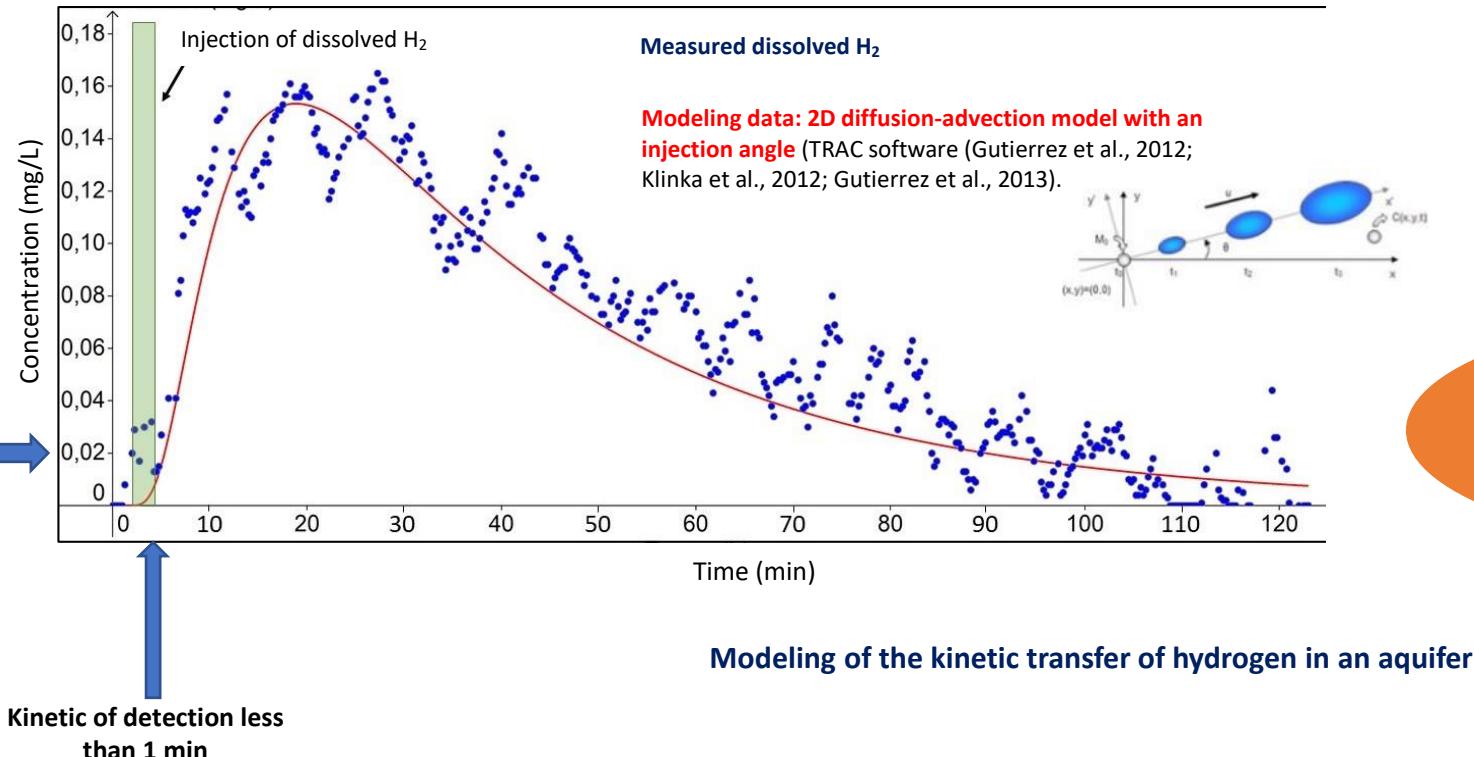
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2020

Context: Hydrogen monitoring in aquifer environment

Experimental site of INERIS (Cattenoy, France)

Risks and Opportunities of geological STORAGE of Hydrogen in salt cavities in France and Europe



- First survey of aquifer
- Detection limit of dissolved H₂
- Kinetic of H₂ dispersion in aquifer

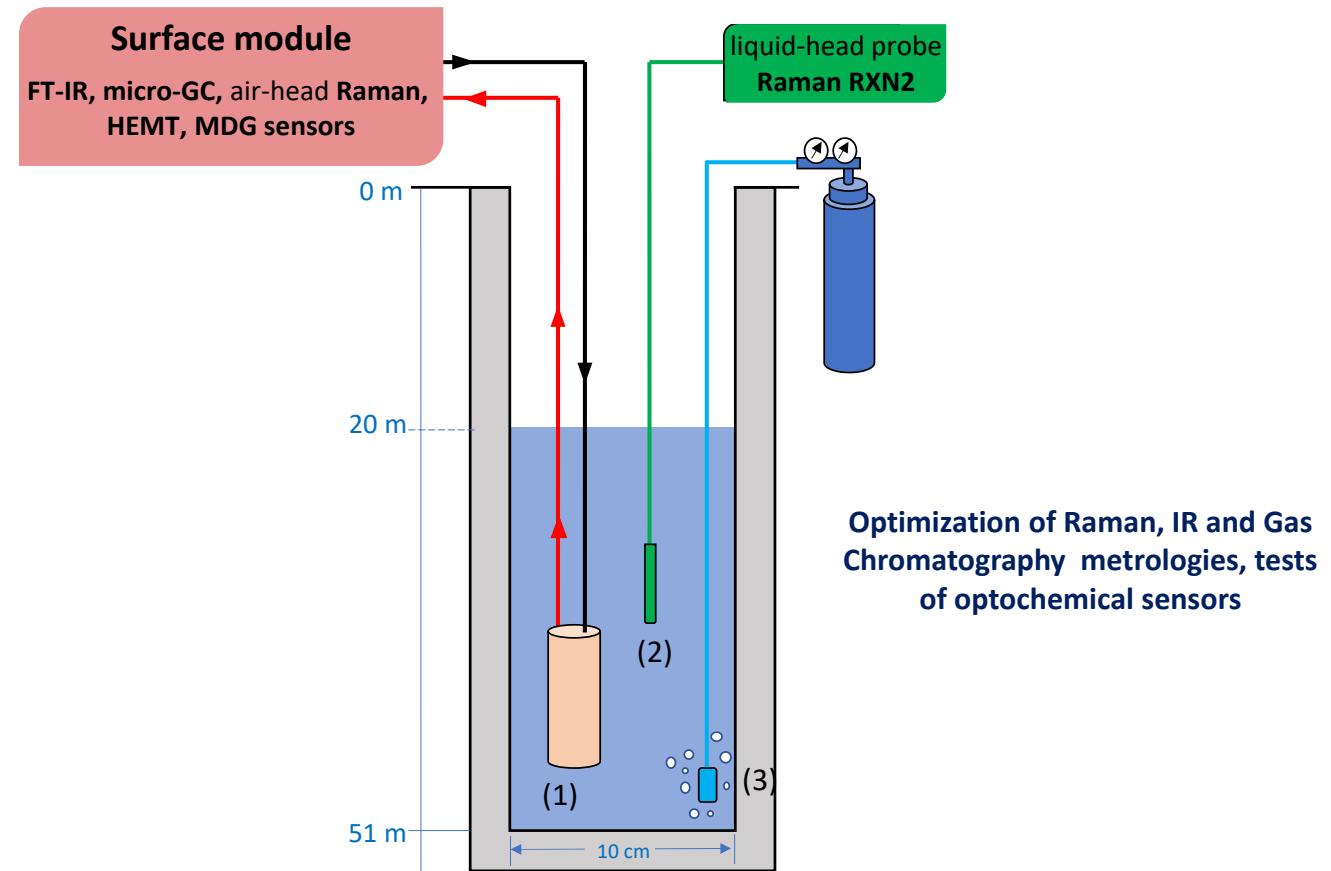
2021



Context: Multi-parameter monitoring in drilling via optical fiber

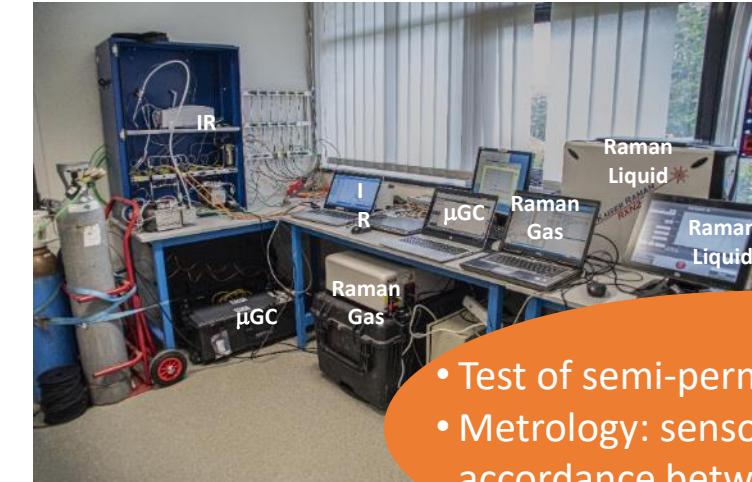
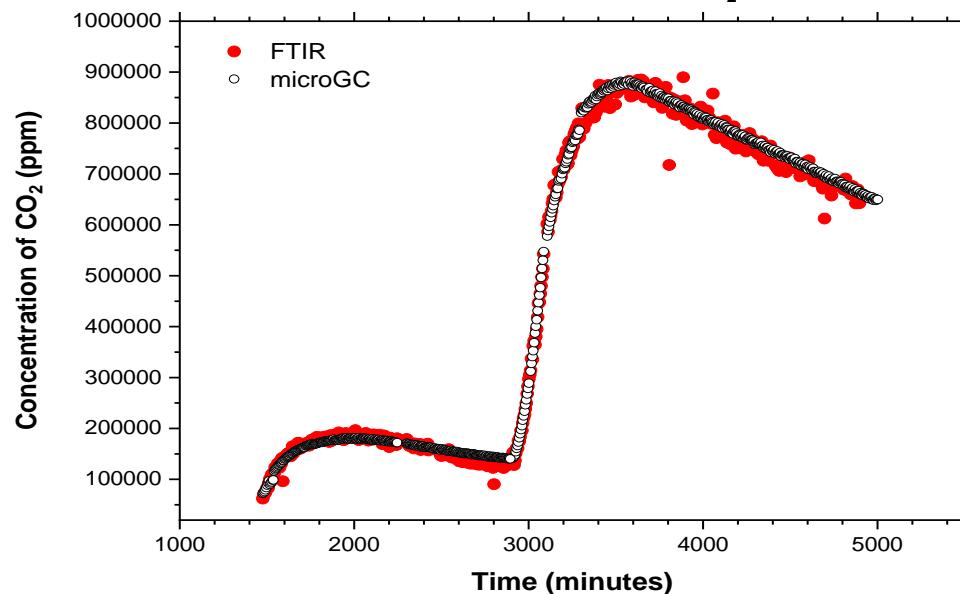
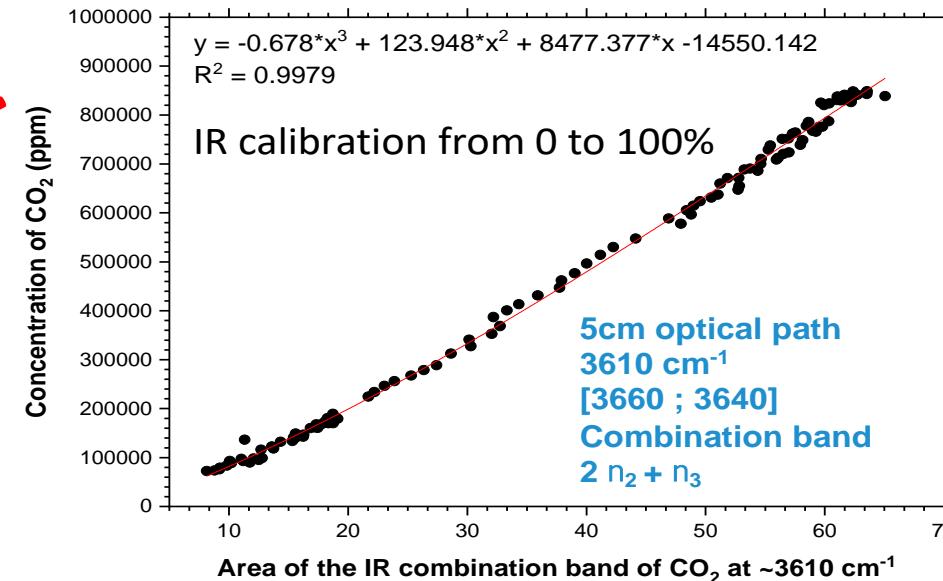
Experimental site of SOLEXPERTS (Vandoeuvre-lès-Nancy, France)

Multi-sensors calibration in an experimental well

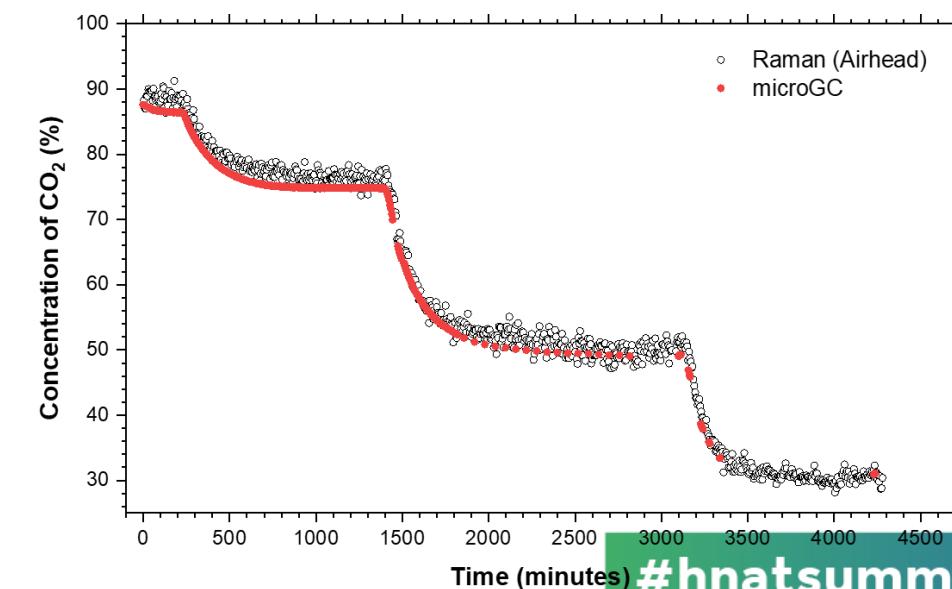


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2021



- Test of semi-permeable membrane
- Metrology: sensor calibration, good accordance between FT-IR, microGC, Raman



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since 2021....

Miniaturization of SysMoG™

Working in high pressure conditions

Dissolved gas monitoring including H₂

Quick gas exploration system based on SysMoG™ probe.....

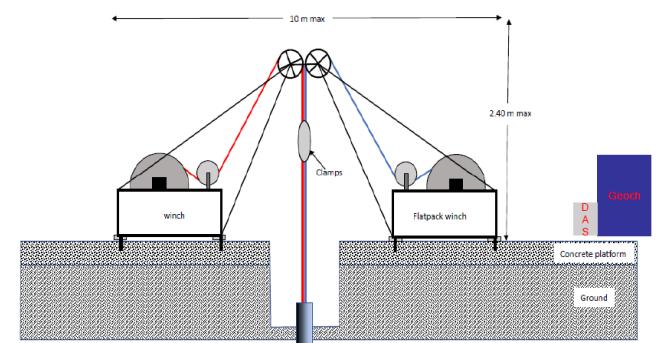
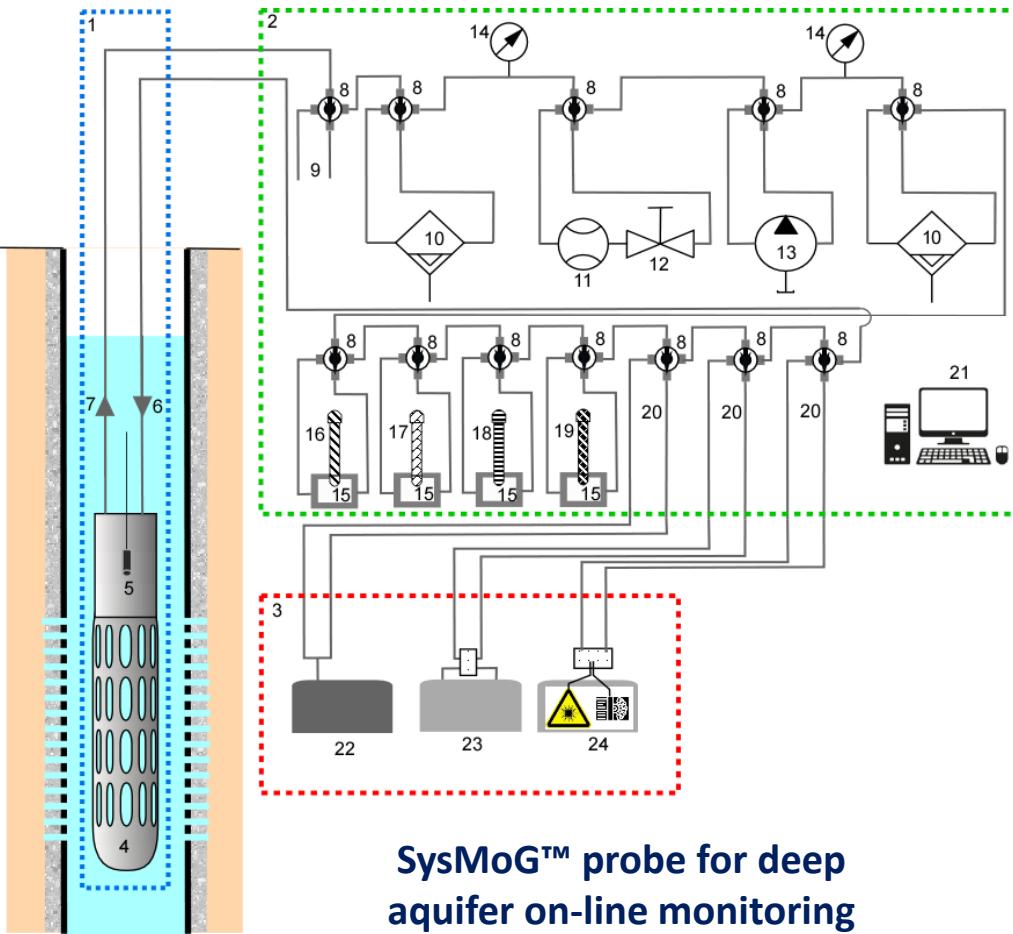
2022



Context: Methane monitoring in deep aquifer

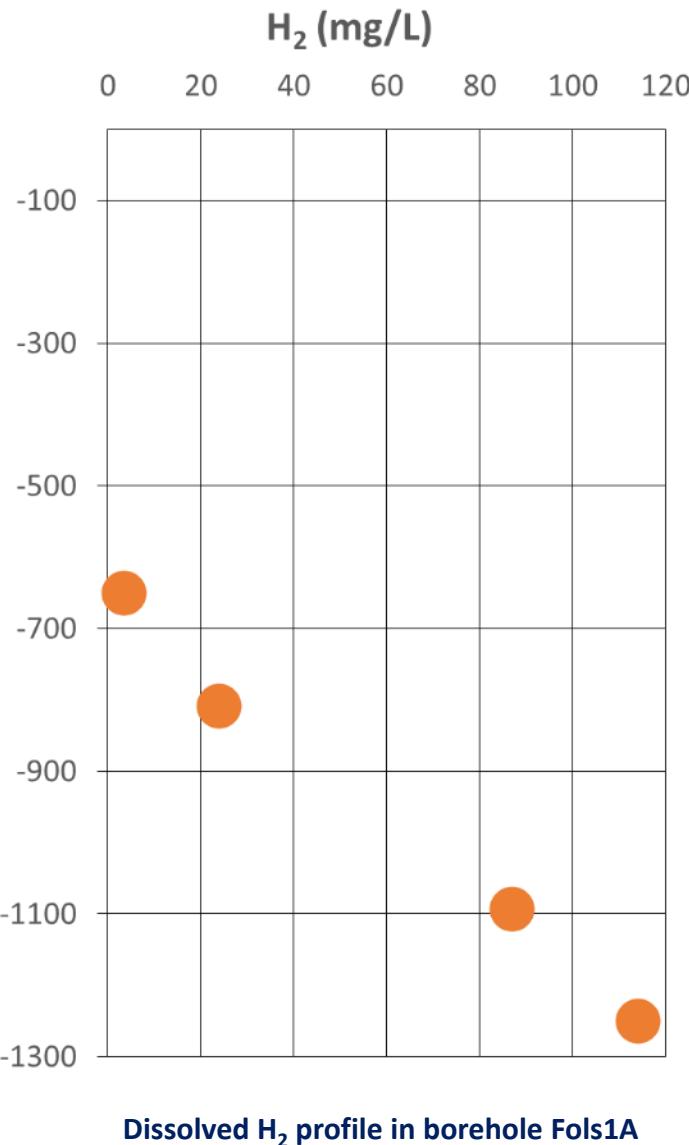
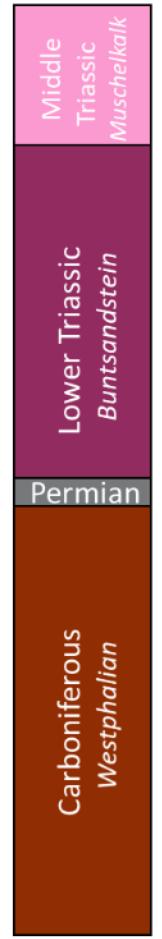
Site of FDE (Folschviller, France) - Regalor project

CBM exploitation of the Lorraine coal gas

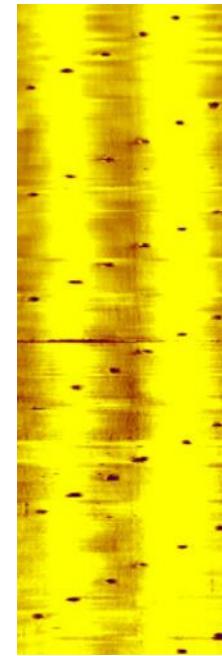


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2022



Perforations borehole Fols1A



- High pressure probe (depth 1500m)
- Miniaturization (OD 54 mm)
- Continuous measurement
- Increase of dissolved H₂ with depth
- H₂ resource estimate around 250 Mt

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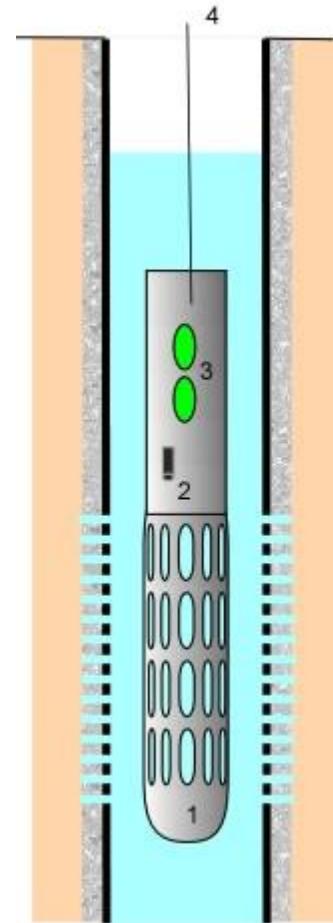
2023



Context: Gas sampling in deep aquifer

Different sites of FDE (France)

He, H₂ exploration



- 1 Borehole gas probe (Patent submitted)
- 2 Down hole pressure/temperature sensor
- 3 Samplers 75 ml
- 4 Rochester cable



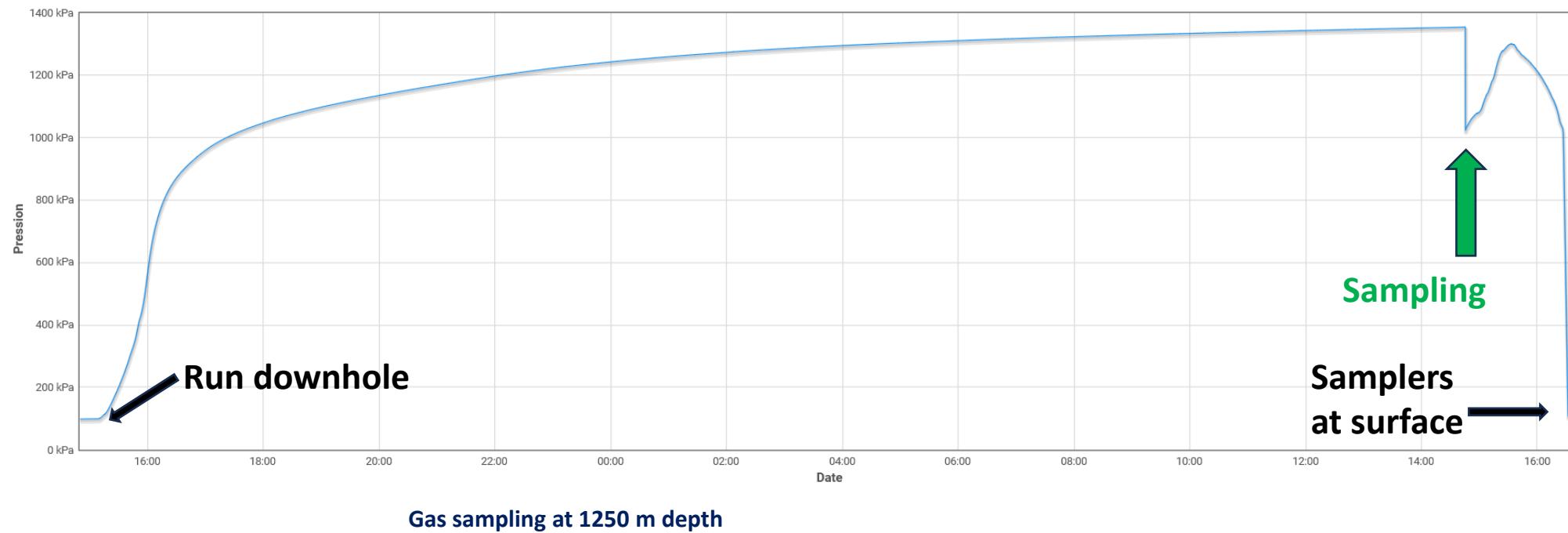
SysMoG™ GH₂ASBUSTERS

H₂ Exploration

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2023

- Optimization sampling time
- Mobile GH₂ASBUSTER unit
- Measurement by well production

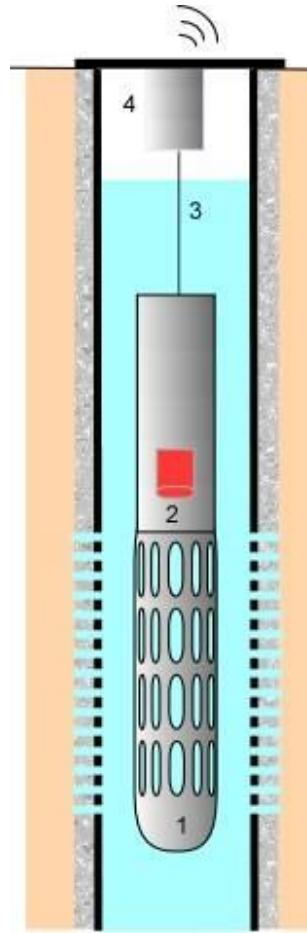


2024

Context: Fast gas monitoring

Gas storage or production

Volcanology – seismic survey – Lake & sea



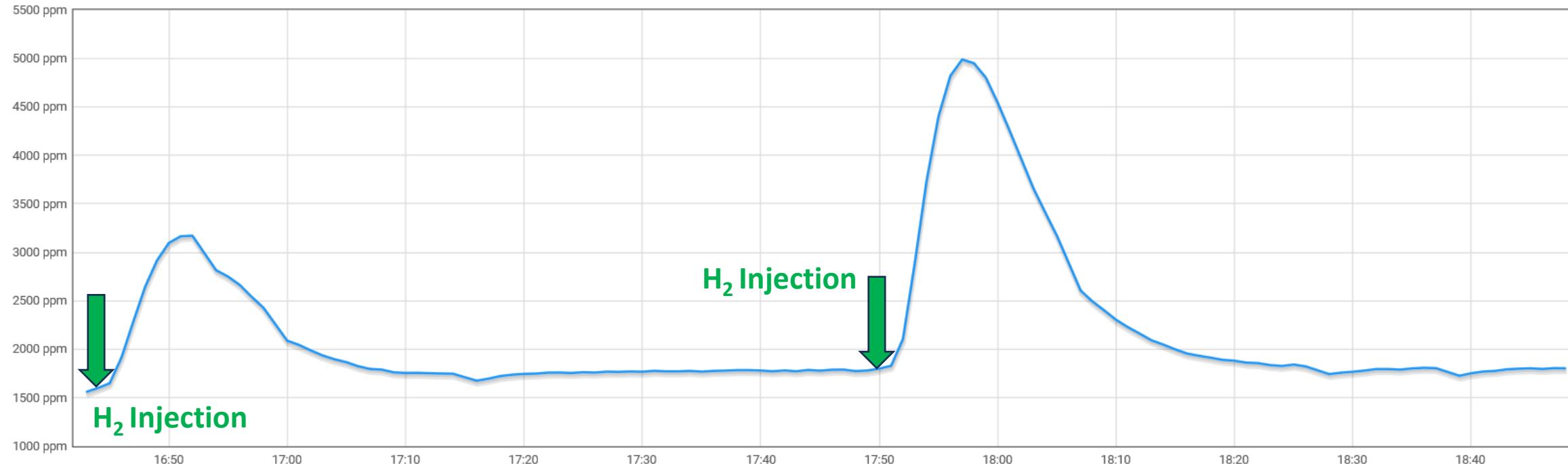
- 1 Borehole gas probe (Patent submitted)
- 2 Down hole gas sensor
- 3 Signal cable
- 4 IOT Logger with data transfer



ShallowMoG™ probe

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2024



- On-line measurements
- CO₂, CH₄, H₂, NH₃
- IOT data access

On-line measurement in Solexperts test borehole with H₂ pulse injections

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Thanks for your attention

For more information and discussion, we look forward to seeing
you at our booth n°11

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