TCCS8, Trondheim, 18/06/15

F5 Well integrity

ULTimate CO_2

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1:1 scale wellbore experiment for a better understanding of well integrity in the context of CO_2 geological storage, Mont Terri underground rock laboratory

JC. Manceau, J. Trémosa, P. Audigane, F. Claret, L.J. Wasch, F. Gherardi, O. Ukelis , A. Dimier, Y. Lettry, T. Fierz

Presented by Christophe Nussbaum

(Swiss Geological Survey, swisstopo)

Geoscience for a sustainable Earth brgm swisstopo SOLEXPERTS Swiss Precision Geomonitoring TNO innovation for life Consiglio Nazionale delle Ricerche EIFER European Institute for Energy Research OBAYASHI

Well integrity: **condition** that **maintains isolation** of geologic formations and **prevents vertical migration** of fluids

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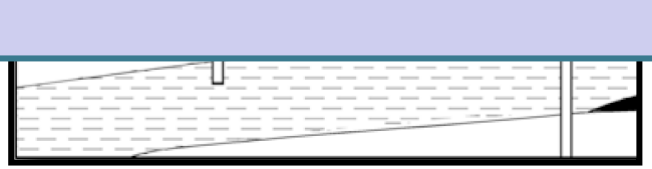
Objective:

follow the evolution of the hydraulic conductivity of a well with temperature changes, pressure changes and when in contact with dissolved CO_2



Adapted from Gasda, Environ. Geol., 2004

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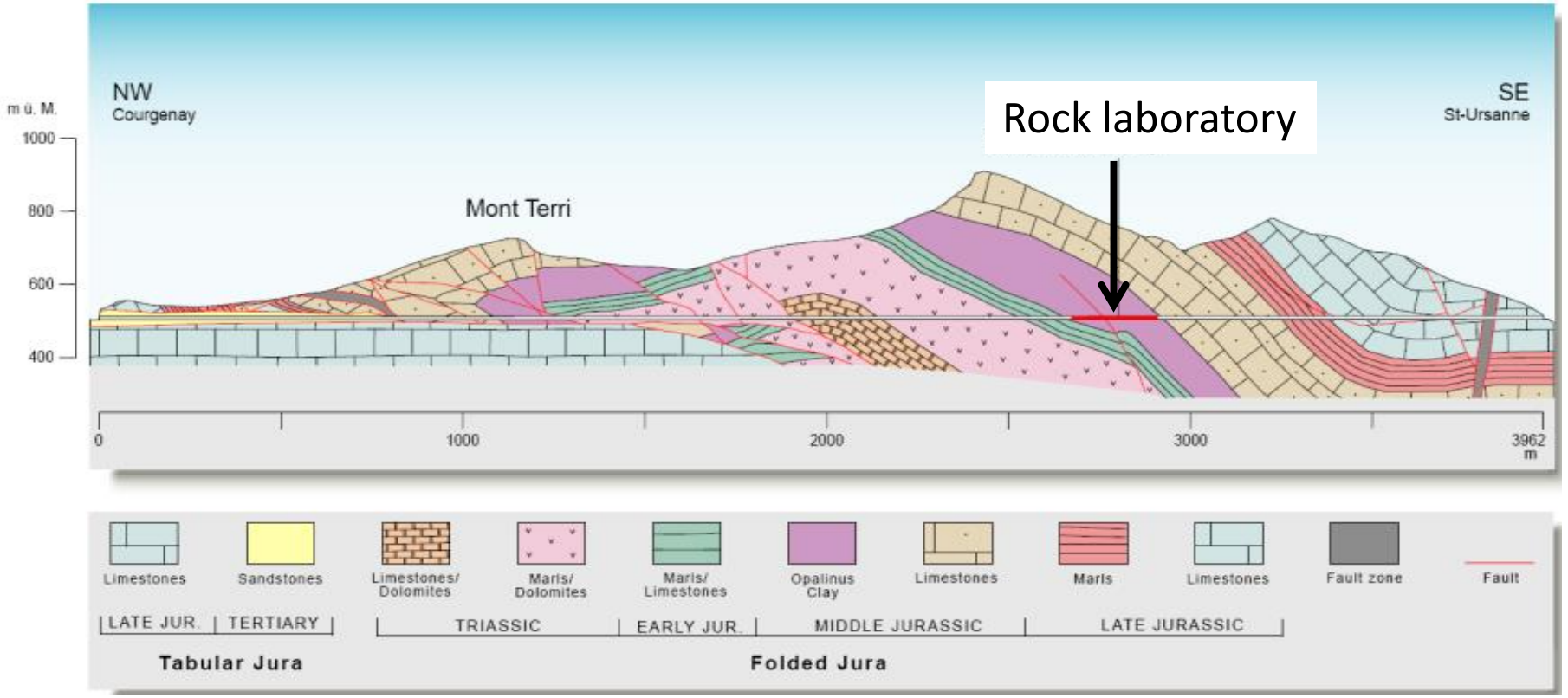
Location of the experiment

Underground Rock Laboratory

of Mont Terri, Canton of Jura



Opalinus Clay: representative of a **caprock** formation

Concept

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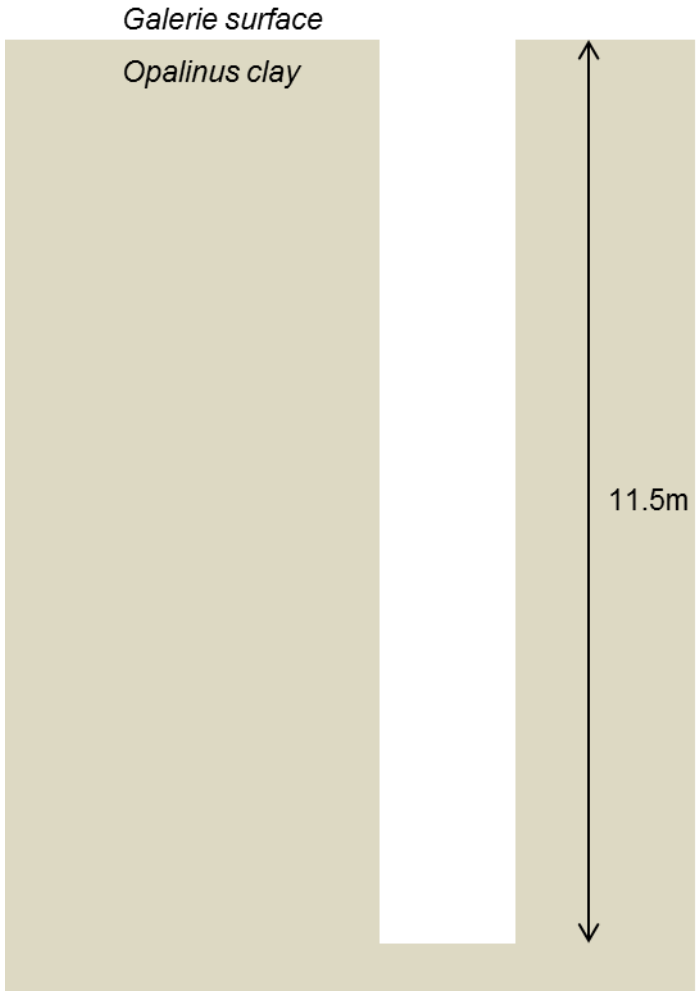

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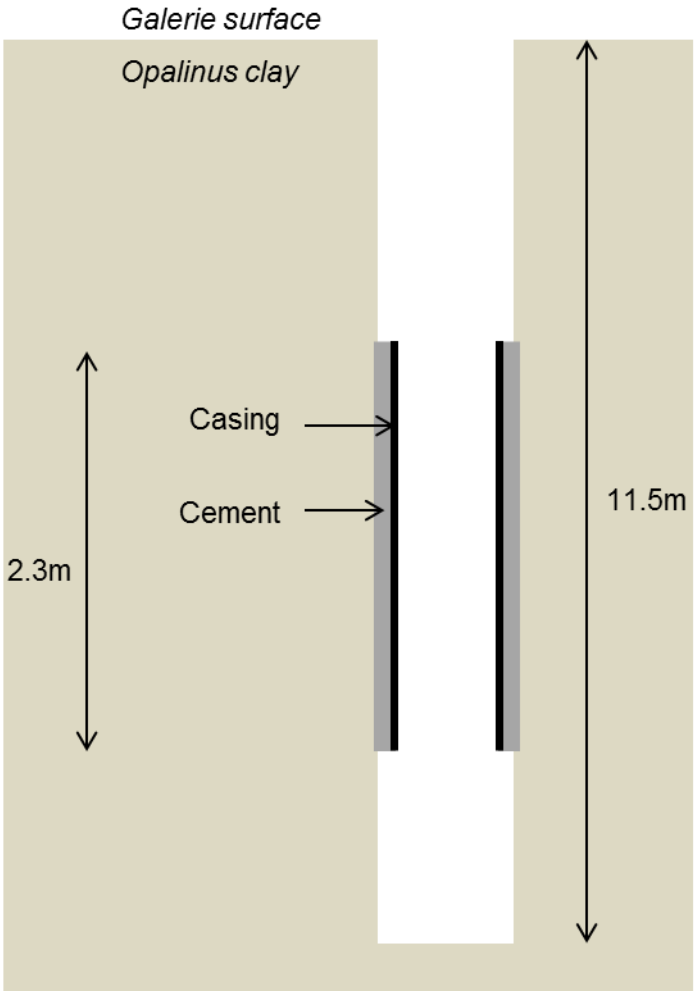
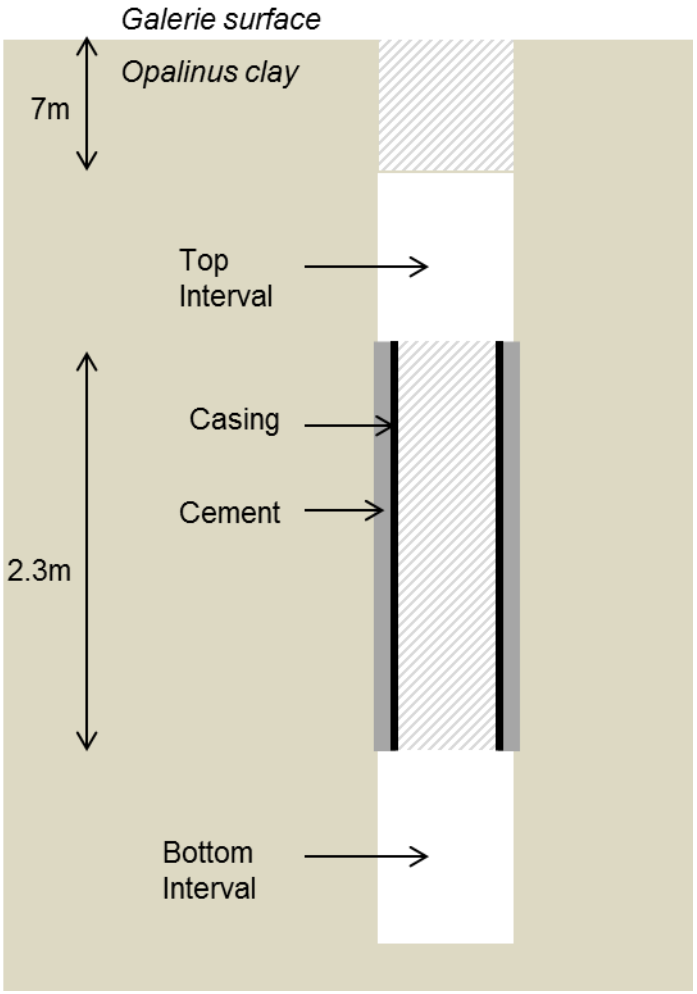
Concept



- Construct a **well section**
  - **Ø198 mm borehole**
  - **5.5 ’’ carbon steel casing**
  - **Class G cement**

Concept

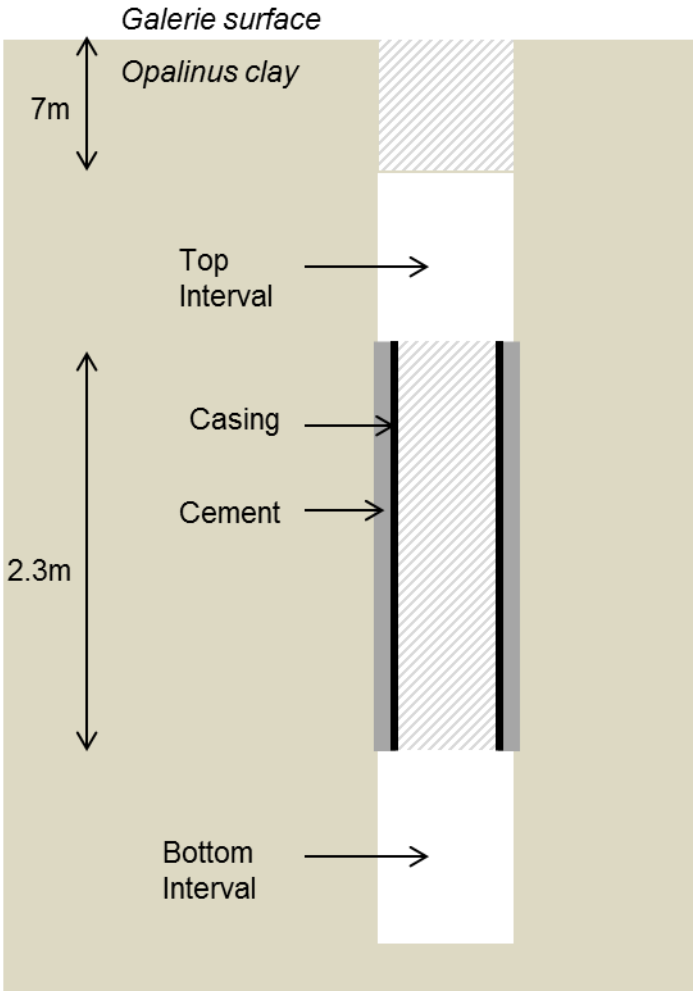


- Construct a **well section**
- Design of intervals for, under different conditions:
  - **Measuring the flow** between the intervals through the well

  ⇒ ***Sealing changes***
  - **Sampling fluid regularly**

  ⇒ ***Fluid composition changes***

Concept



- Construct a **well section**
- Design of intervals for, under different conditions:
  - **Measuring the flow** between the intervals through the well

  ⇒ ***Sealing changes***
  - **Sampling fluid regularly**

  ⇒ ***Fluid composition changes***
- Take samples of the different elements (**overcoring**)

  ⇒ ***Mineralogical changes***

  ⇒ ***Quality of the interfaces (bonding)***

Method for assessing well integrity

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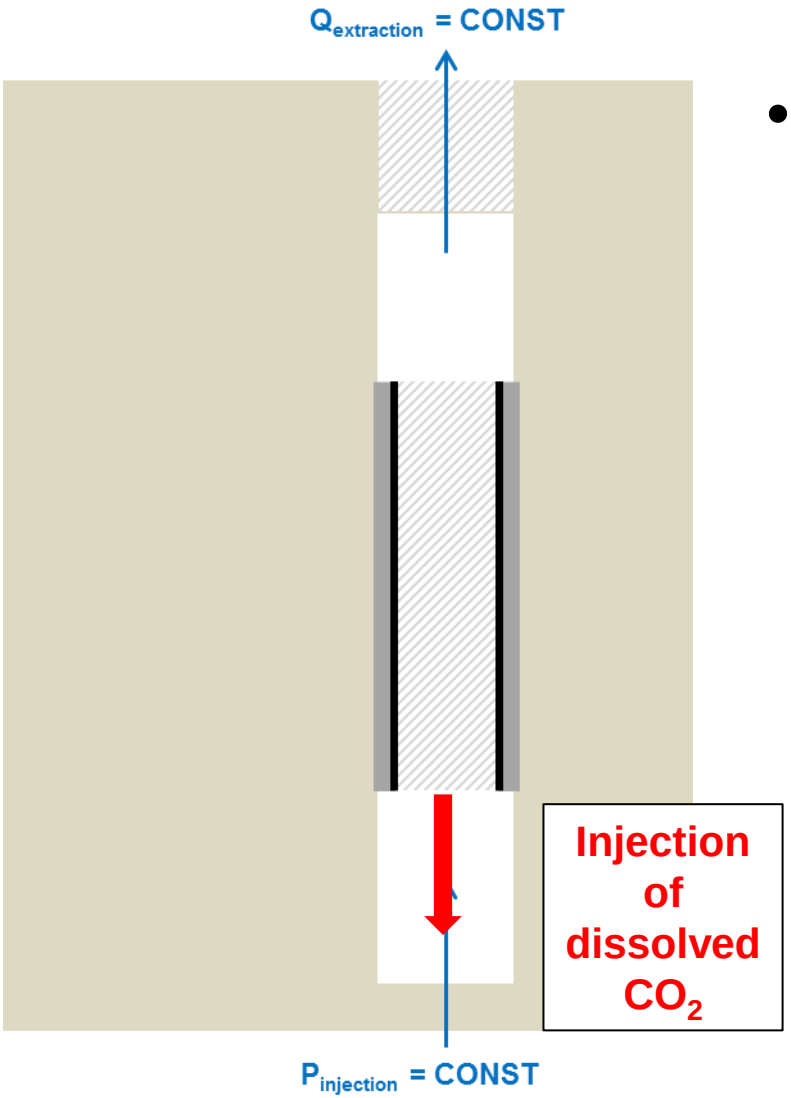

- Force circulation bottom → top:
  - **Effective (equivalent) well permeability** inversion with 2D radial flow modeling (TOUGH2)
  - **Fluid sampling at the extraction line to avoid pressure perturbations**

Continuous characterization of the well system over time:

Period 1: Initial T and pore water composition (02-03/13)

Period 2: Increase of T (05-09/13)

Period 3: Variation of P (10-12/13)

Period 4: Replacement of pore water by CO_2-rich water (02/14-02/15)

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Method for assessing well integrity

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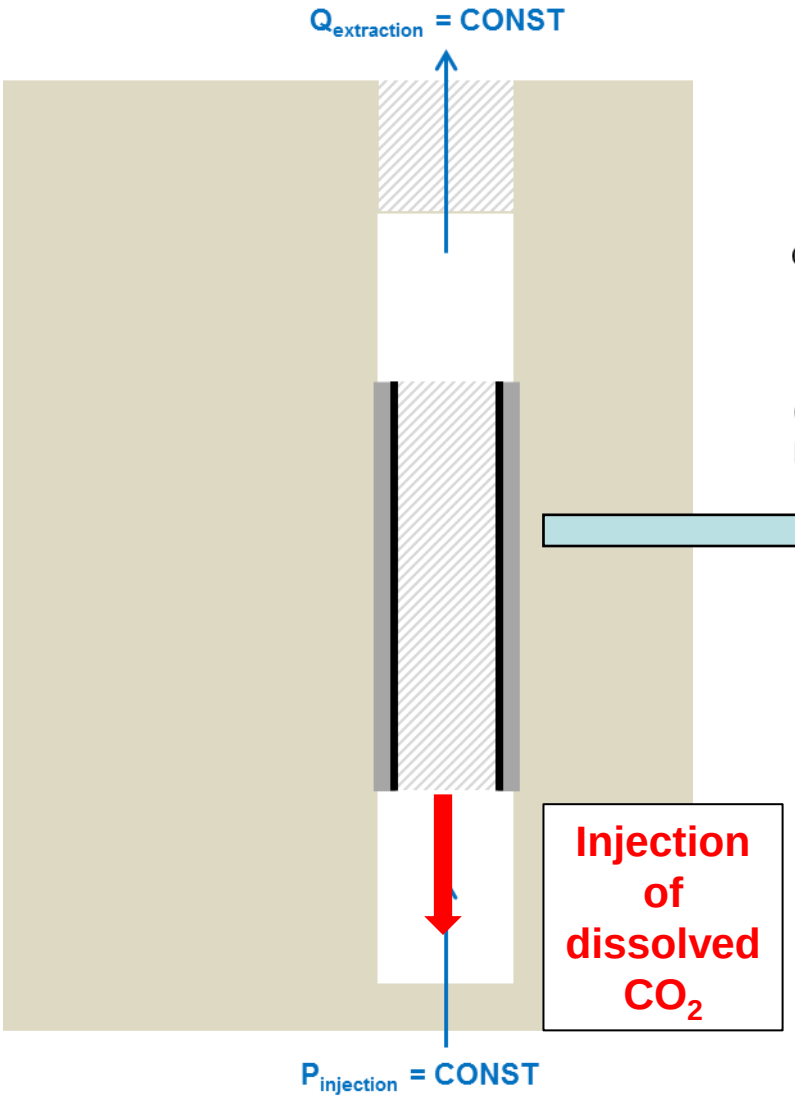

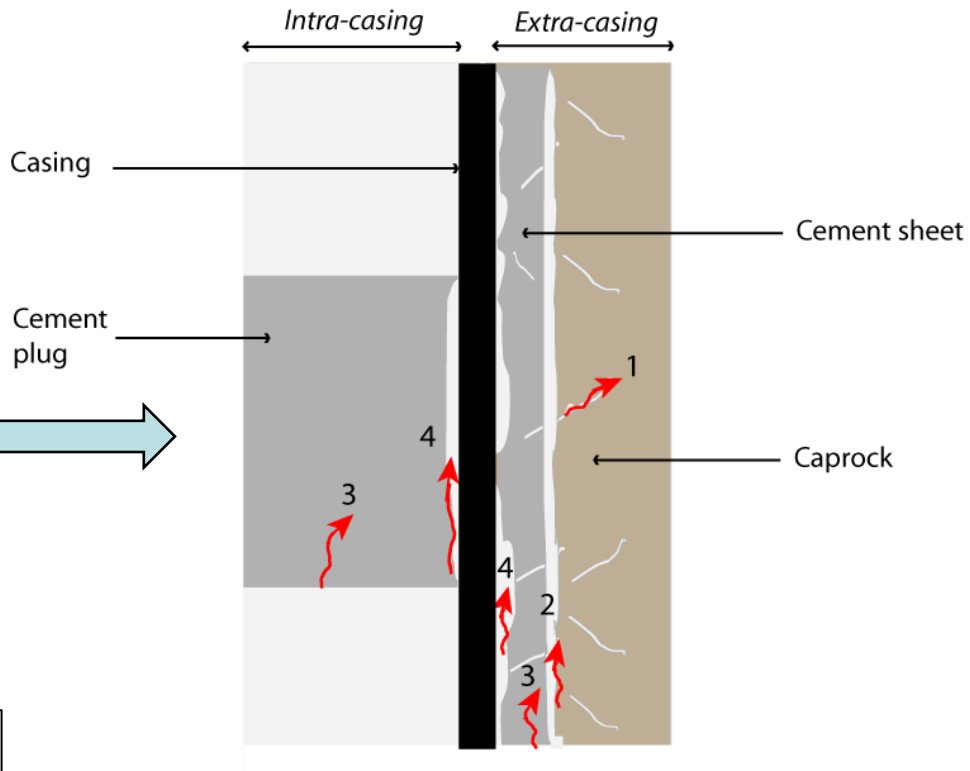

Potential flowpaths for upward migration of dissolved CO_2

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Equipment

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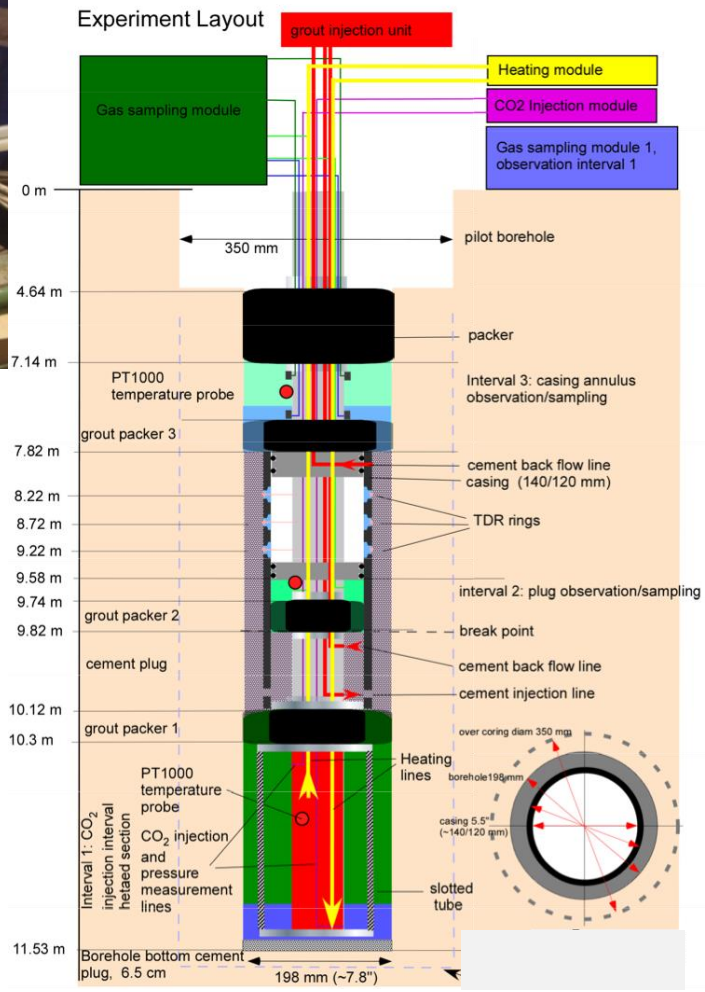

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Drilling and installation

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Assessment of effective well permeability

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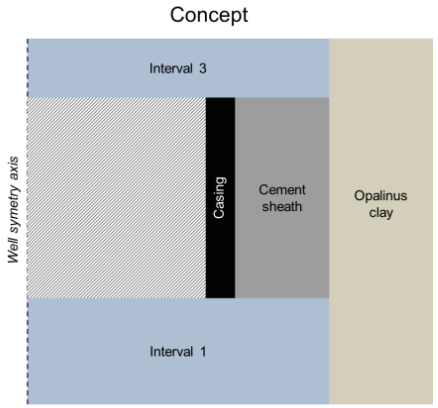
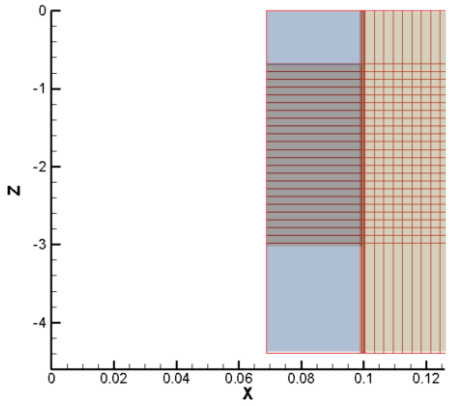
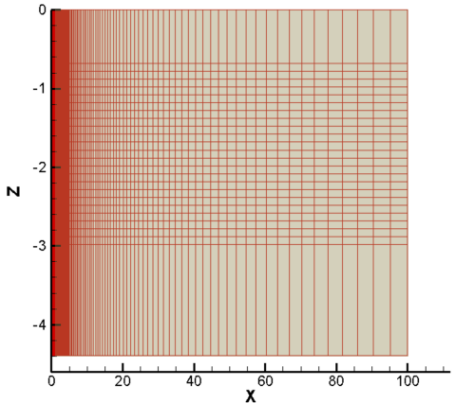
- 2D radial flow modeling (TOUGH2)







- Main output of interest: **effective** well permeability
- Other influential parameters to account for:
  - **Caprock permeability** and **pressure boundary conditions**: derived from pressure relaxation tests
  - **Intervals compressibility**: computed at different times from independent tests

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Validation of the hydraulic model

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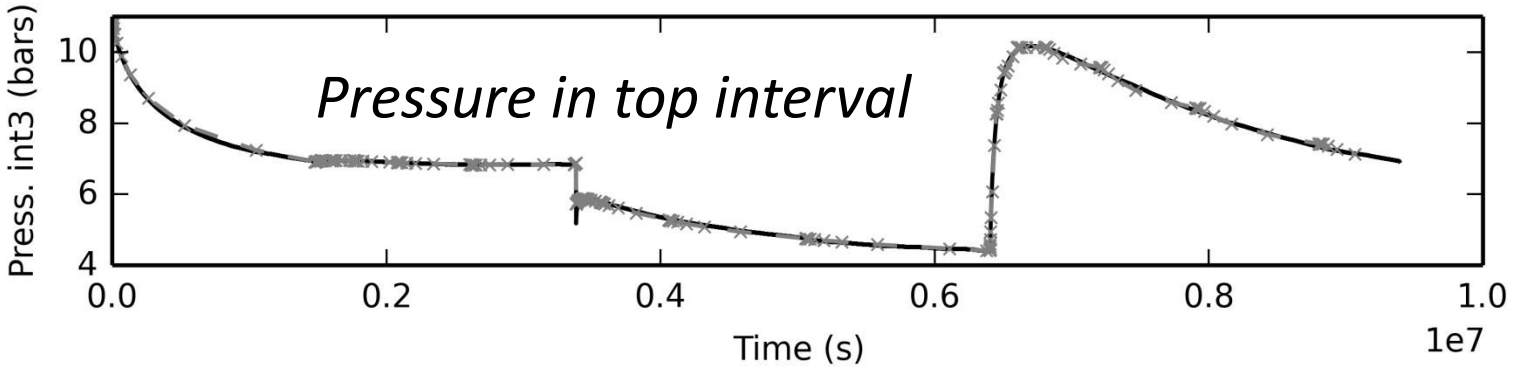
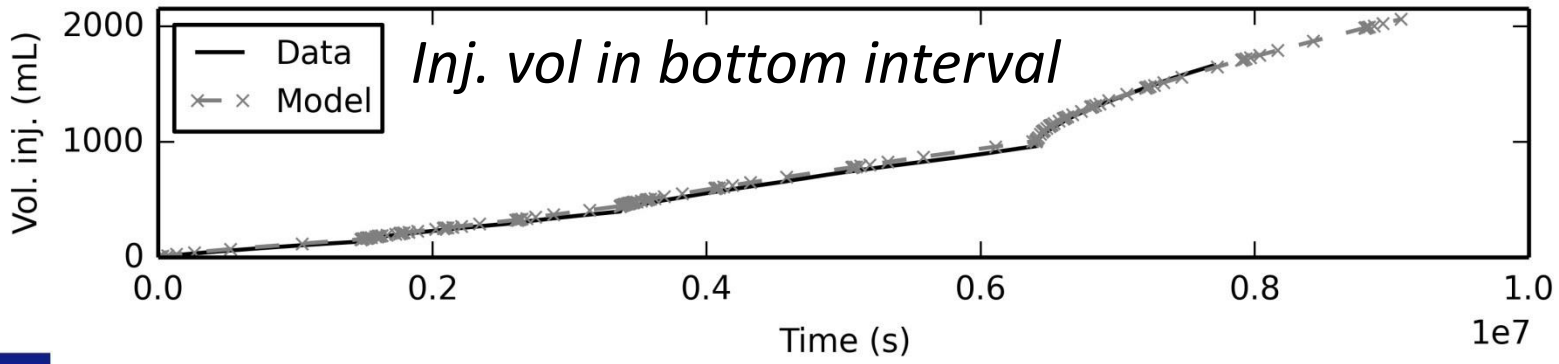
- Data/model matching in terms of **pressure** in top interval and **injected volume** (mass balance) in bottom interval
  - Ex. period 3 (large variations of pressure)





Results: effects of temperature

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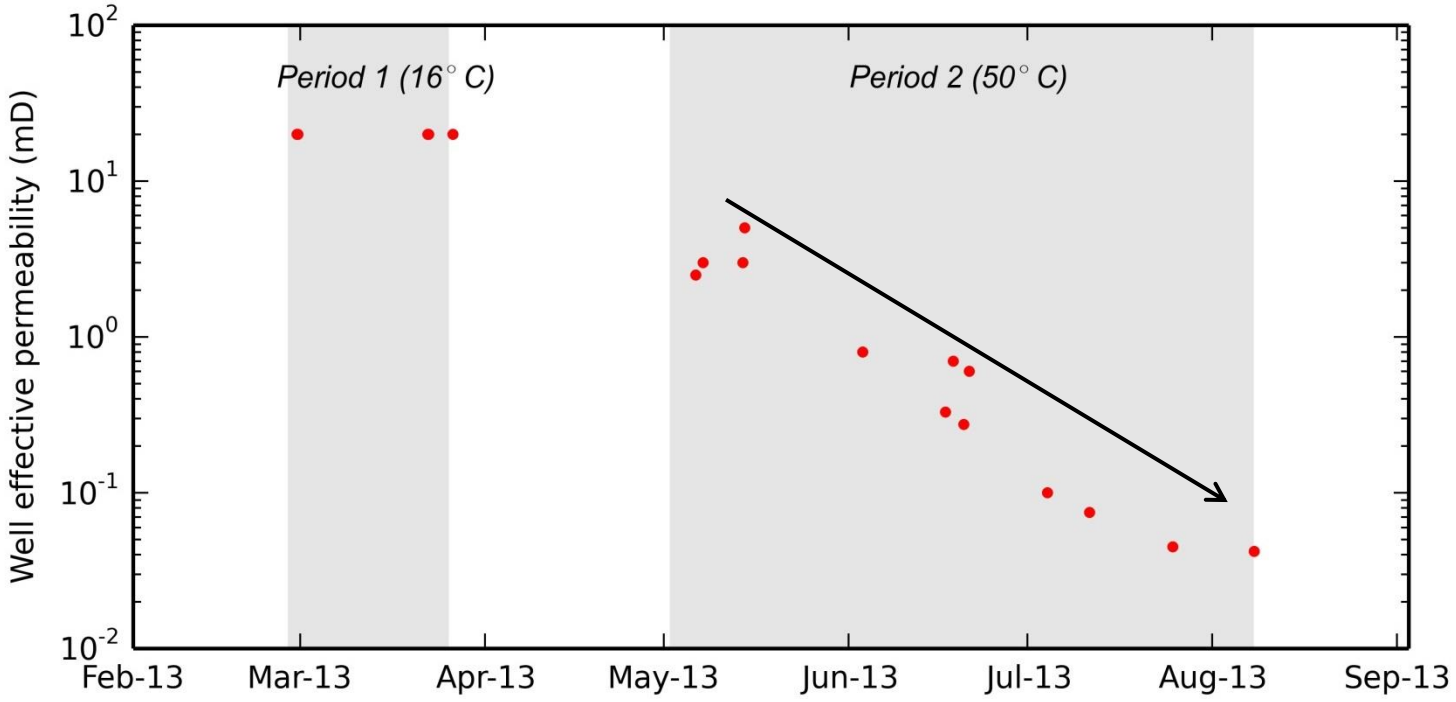
- A **large decrease of K_{eff}** is observed.
- The model shows that the **K_{eff} decrease** seems to occur **in the lower part of the well** (where **larger T increase** occurs)
- Hypotheses:
  - **Rock/material thermal expansion**
  - But also **mineral precipitations, clogging by fine particles**, or **natural borehole convergence**



Results: effect of P_{bottom} increase

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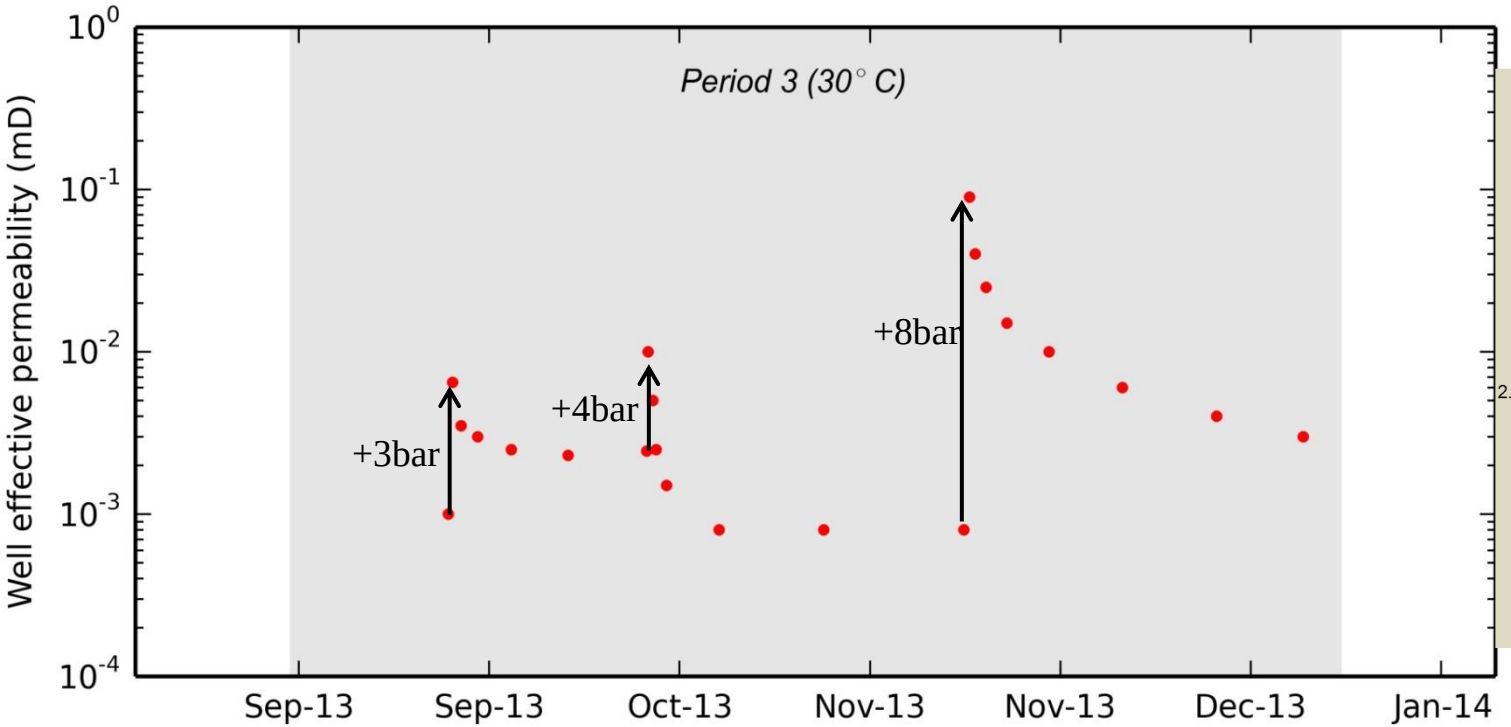
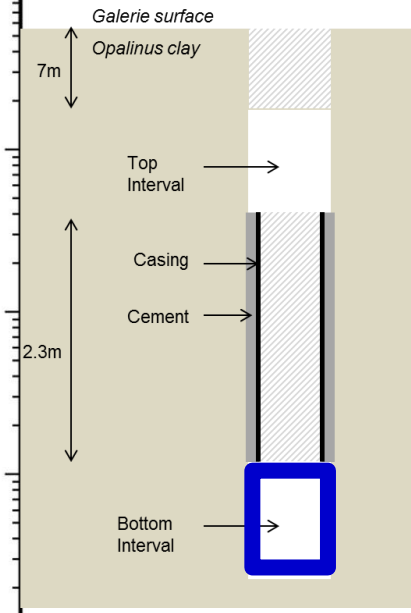
- **K_{eff} dependant on P_{bottom}**: could be a sign of flow through annuli/interfaces





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Flow through annuli/interfaces: insights from water chemistry *(top interval)*

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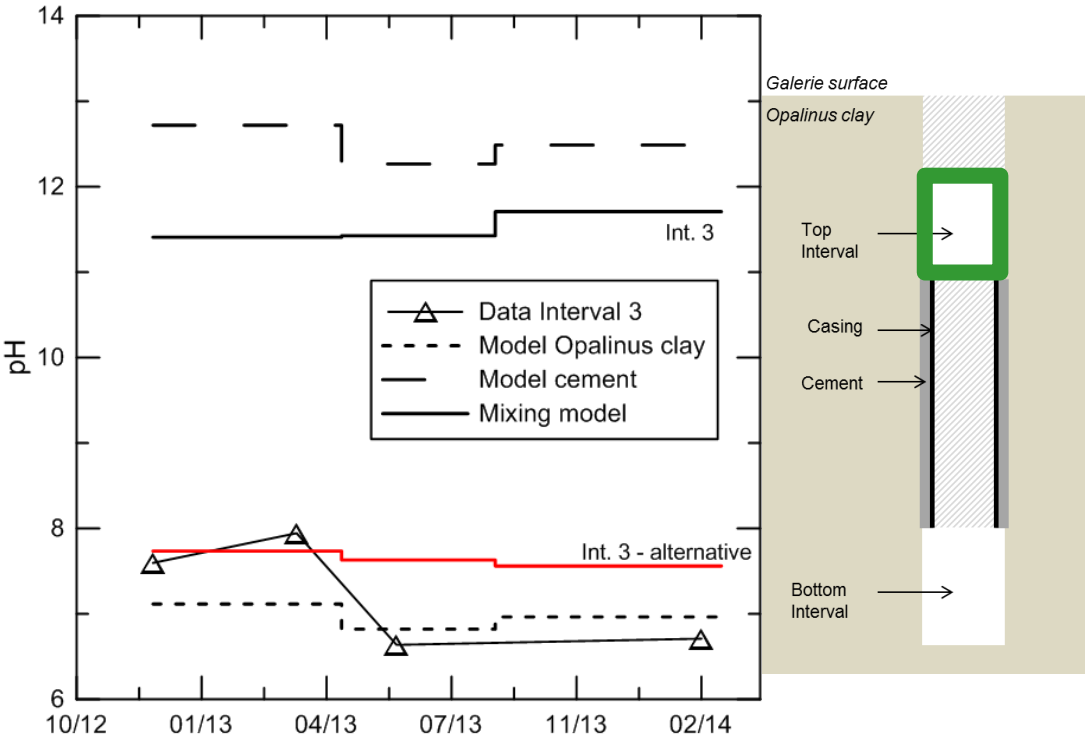
- Solutions from intervals sampled over time
- Geochemical model using PhreeqC v3: uses the water flow **from the cement annulus** and **to the formation**
- Solution composition in top interval could be explained by a **channelized flow** without passing through the cement porosity



Before adding CO_2 !

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Period 4: Flow of CO_2 rich water

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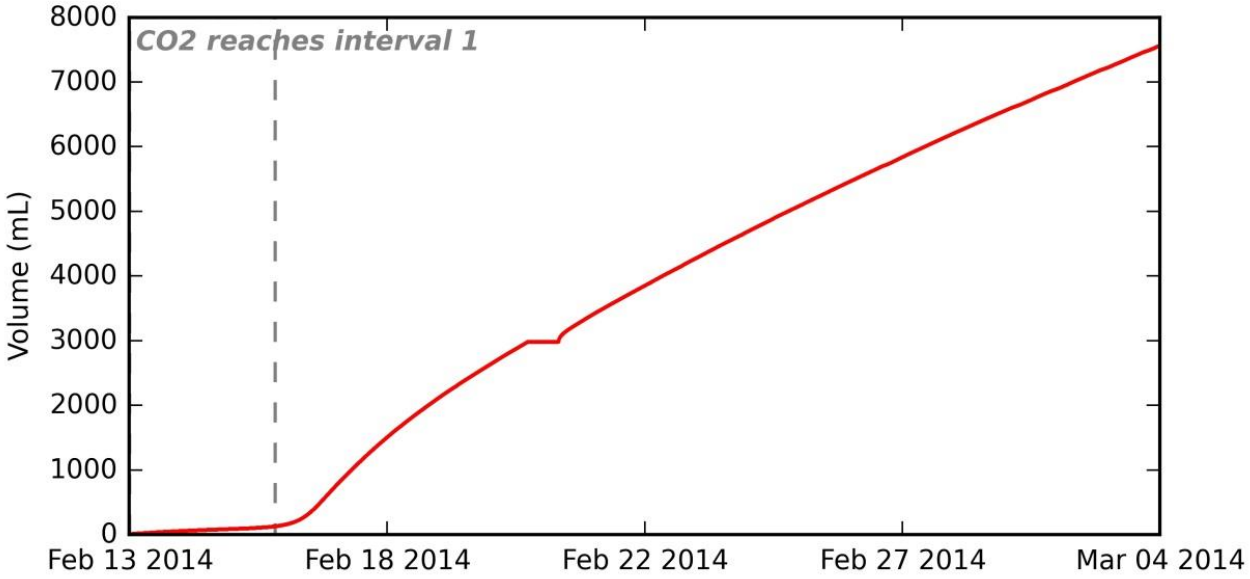
- 1- CO_2 (isotopically-marked + tracers) bubbling directly at the bottom of the bottom interval = quantity computed to avoid any exsolution:



- 2- Same process than before the CO_2: CH injection of water with CO_2 (and tracers) dissolved in a surface pressure vessel

Results: effects of CO_2

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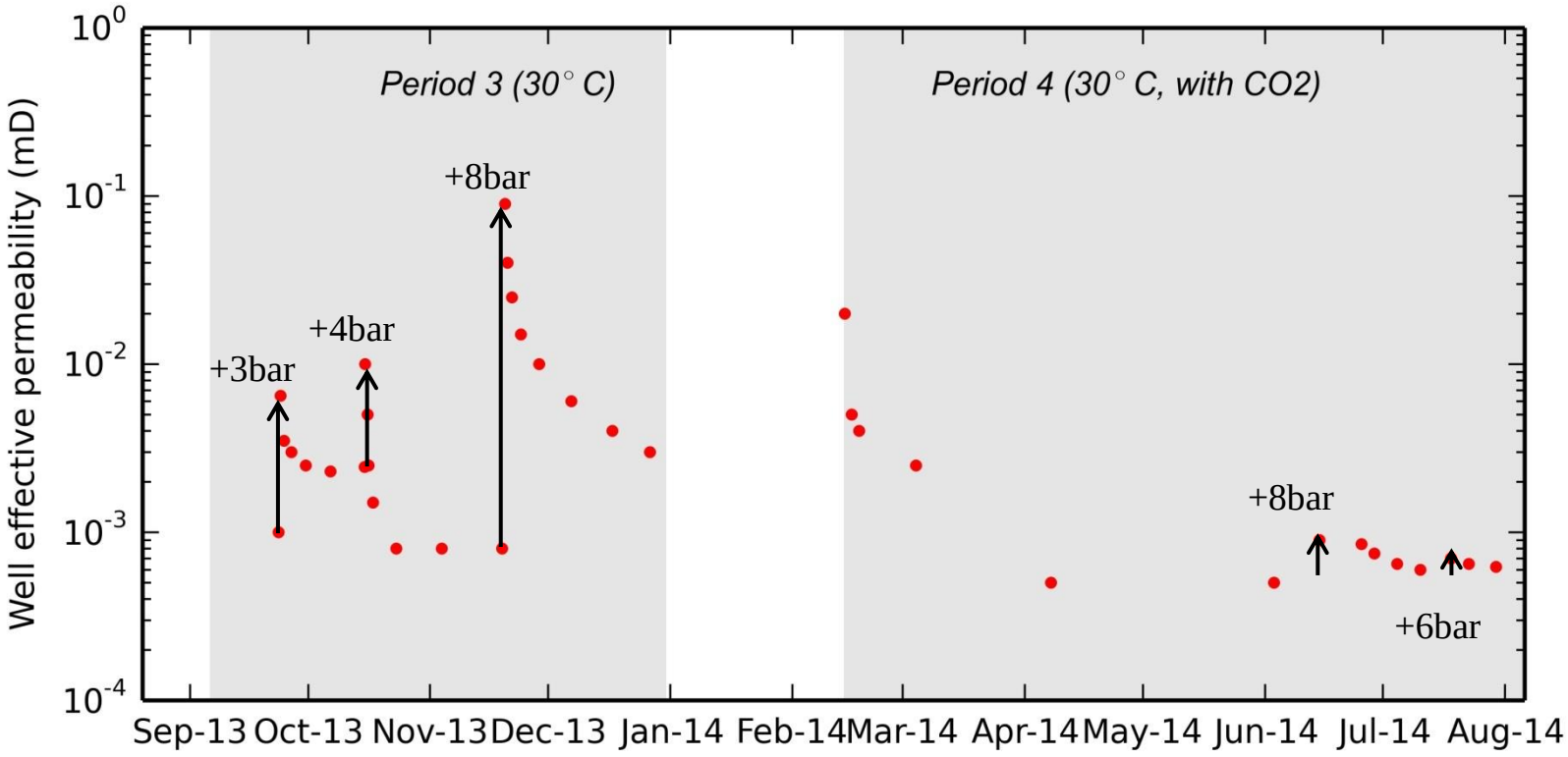
- Lower effect of pressure increase: sign of **carbonation** at annuli/interfaces ?



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Carbonation at interfaces ?

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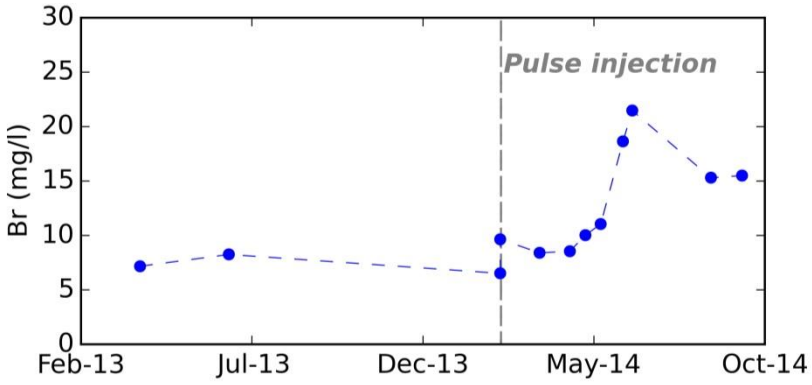
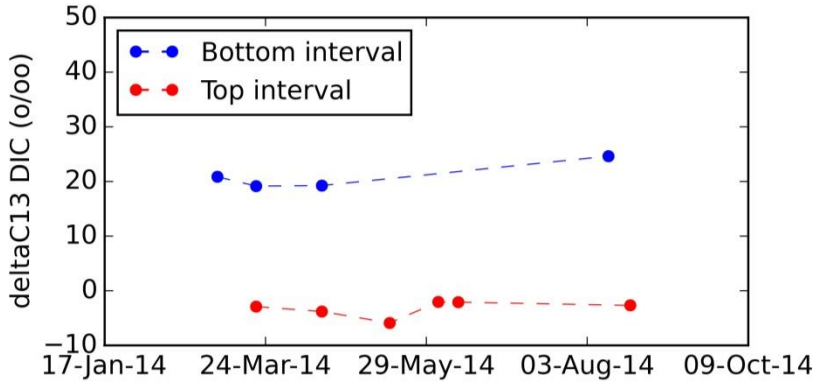
- Bromide pulse injected at the beginning of the CO_2 injection and **detected** in the **top interval:**
- **But no influence** observed of the injected CO_2 **on the isotopic signature of the top interval**





[ISTO / Université d'Orléans]

⇒ The injected **CO_2 did not reach the top** and might have been **consumed by the cement**

$\delta^{13}C_{bottom}$ = 19.2 ‰ (injected CO_2)

$\delta^{13}C_{top}$ = - 4.1 ‰ (CO_2 from the pore water formation)

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Conclusions

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- **Ability of the chosen design and of the chosen scale (URL)** to estimate the evolution of the well integrity over time
- Main observations:
  - **K_{eff} decrease with temperature increase**
  - **K_{eff} dependent on the imposed pressure**
  - **Dissolved CO_2 limits the pressure effects**

- The contact between the well and CO_2 is now stopped and lasted one year
- **Final overcoring is in progress**: link these preliminary observations with mineralogical observations (mineralogical changes and quality of interfaces)