ULTimateCO2: the underground rock laboratory experiment of Mont Terri

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Well integrity assessment under temperature and pressure stresses by a 1:1 scale wellbore experiment

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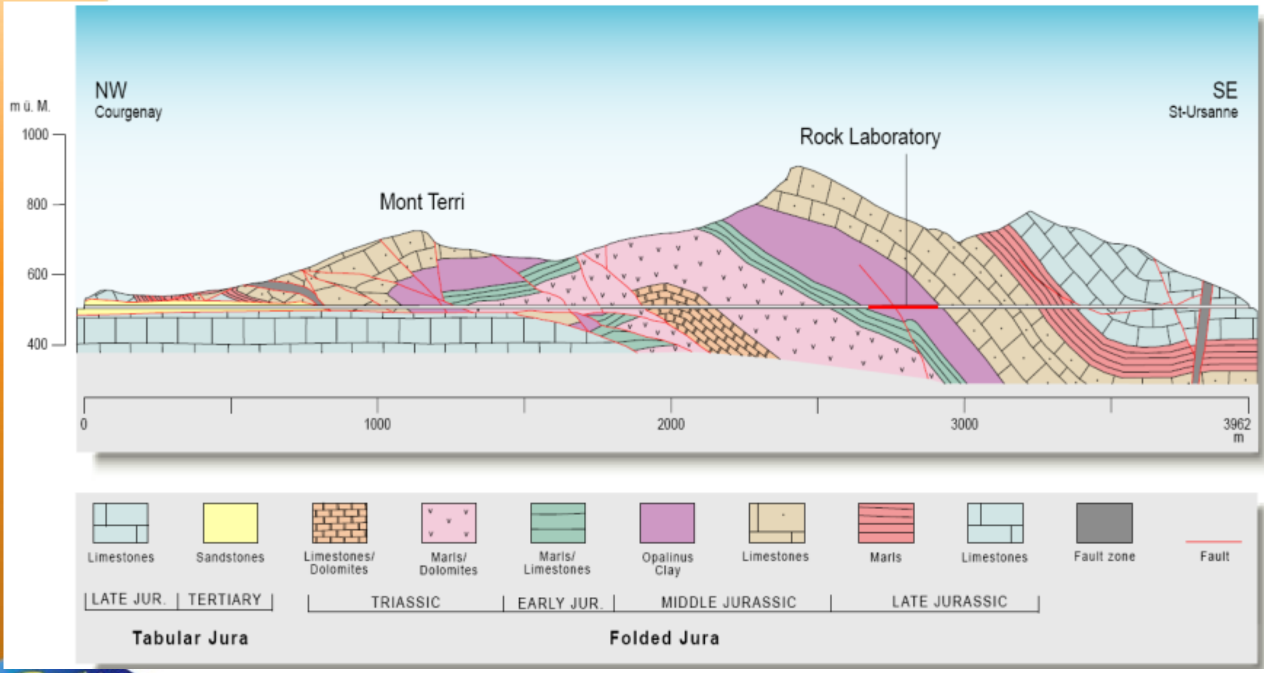
Motivation and objective

- **Laboratory (core scale) studies for well integrity assessment:**
  - hydraulic properties of well elements
  - cement carbonation rates analysis
  - casing corrosion
    - Interface of well elements (casing – cement – rock)
- **Field scale studies for well integrity assessment:**
  - vertical interference tests for well system equivalent permeability
  - study on CO_2 producer samples

- Objective of this study:
  - evaluate the behavior of the entire well system at an **1:1 scale** over time, time due to changes in well conditions: **pressure**, **temperature** and **fluids** in contact with the well (CO_2 or not)

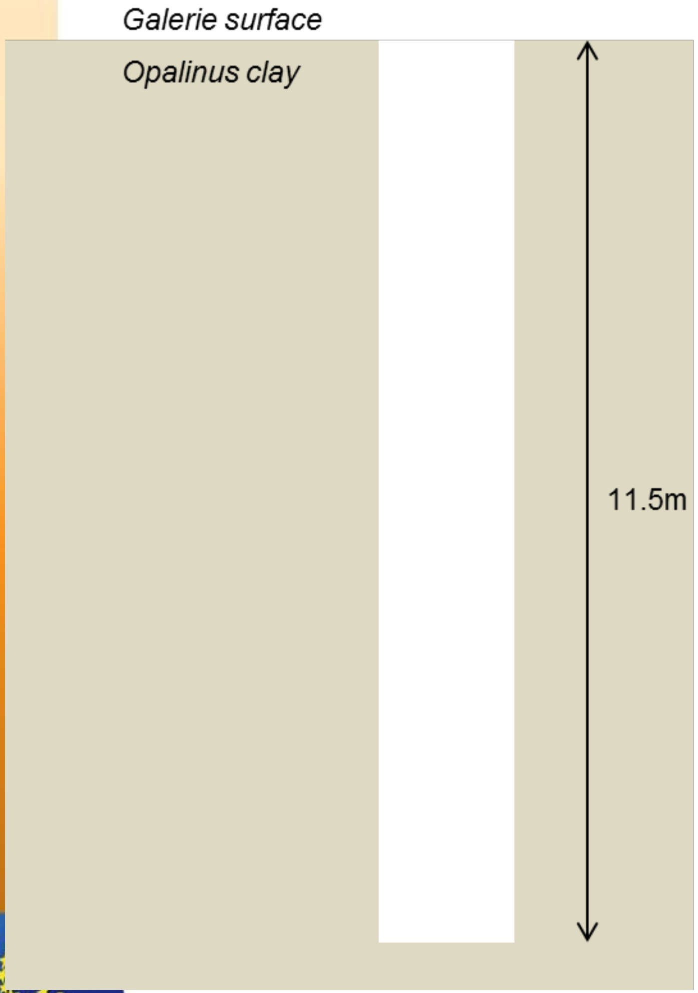
Location of the experiment

Underground Rock Laboratory of Mont Terri, Switzerland



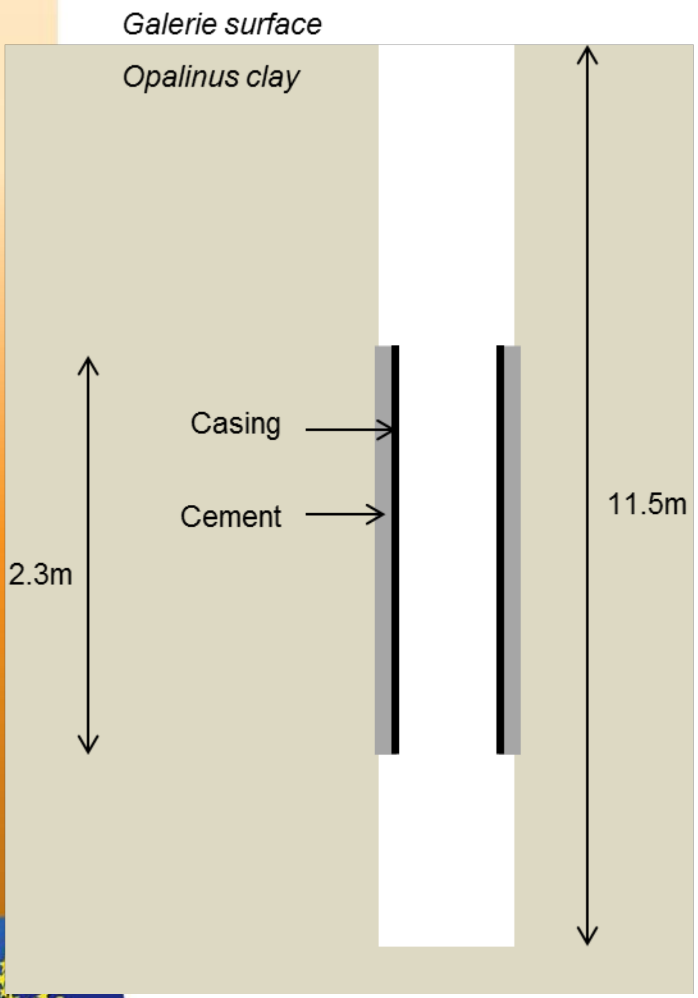
[Mont Terri Project, 2014]

Concept

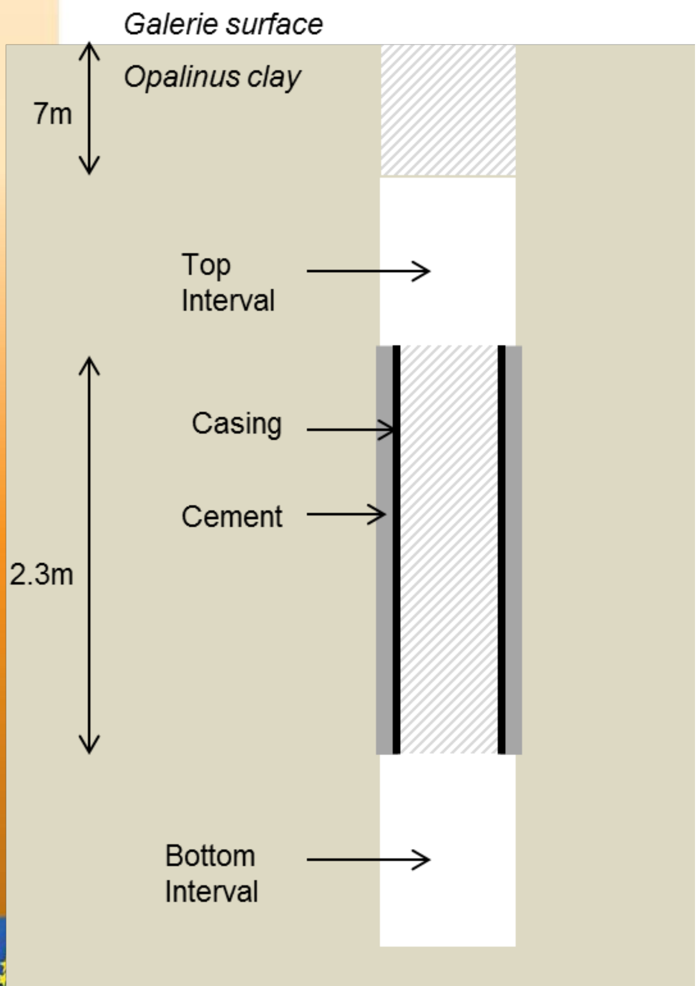


Concept

- Construct a well section

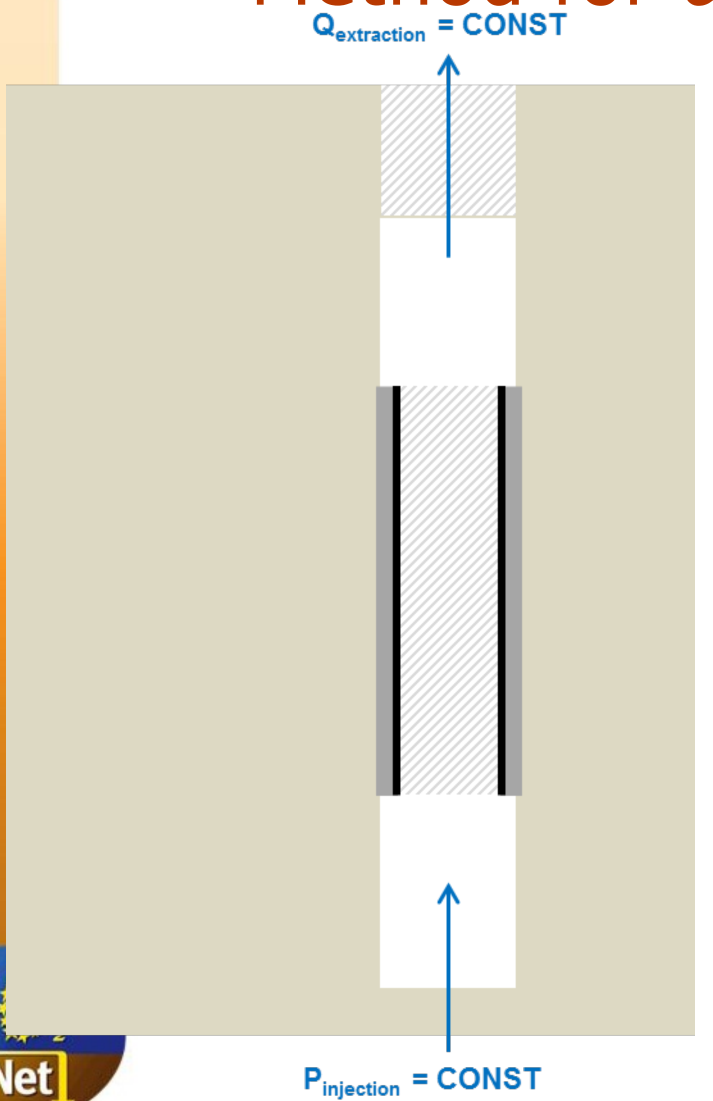


Concept



- Construct a well section
- Design of intervals for, under different conditions:
  - between the intervals through the well
  - Measuring of the flow inside and outside the casing
  - ⇒ *Sealing changes*
  - Sampling fluid regularly
  - ⇒ *Fluid composition changes*
- Take samples of the different elements (overcoring)
  - ⇒ *Mineralogical changes*

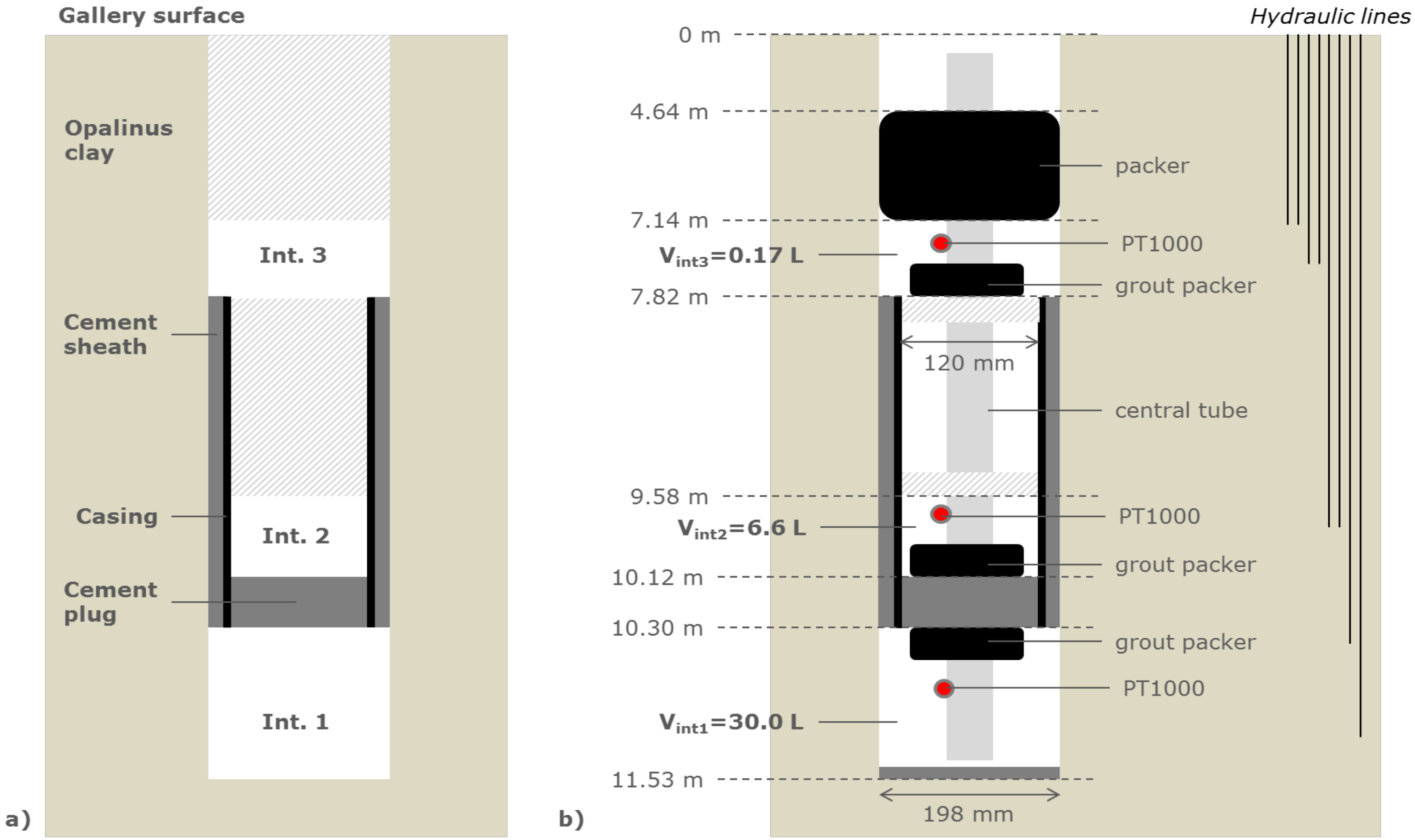
Method for assessing well integrity



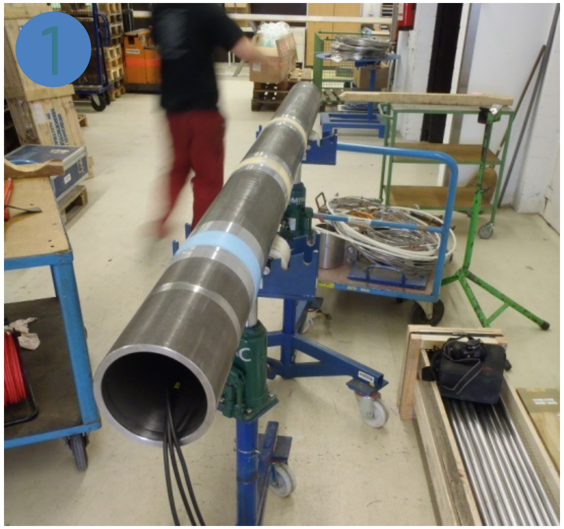
- Create circulation top → bottom:
  - **Pressure difference = equivalent permeability**
  - **Fluid sampling**

- Continuous characterization of the well system over time:
  - **Period 1:** Initial T (16°C), pore water composition
  - **Period 2: I**ncrease of T (50°C), initial pore water conditions
  - **Period 3: D**ecrease of T (30°C), initial pore water conditions
  - **Period 4:** Same T(30°C), pore water + dissolved CO_2

A complex system

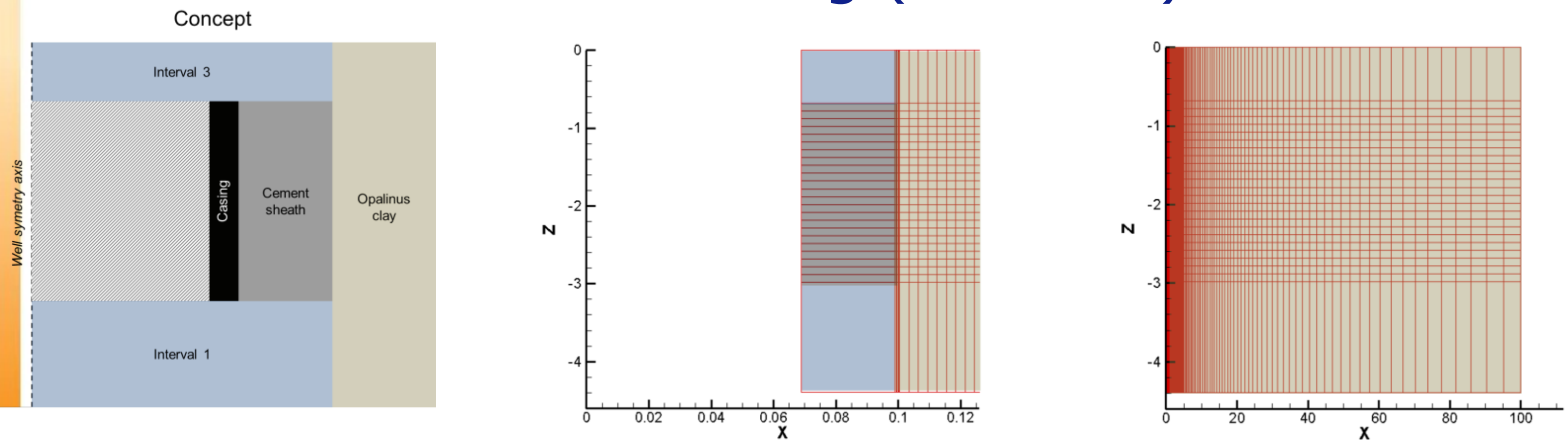


System



Assessment of equivalent permeability

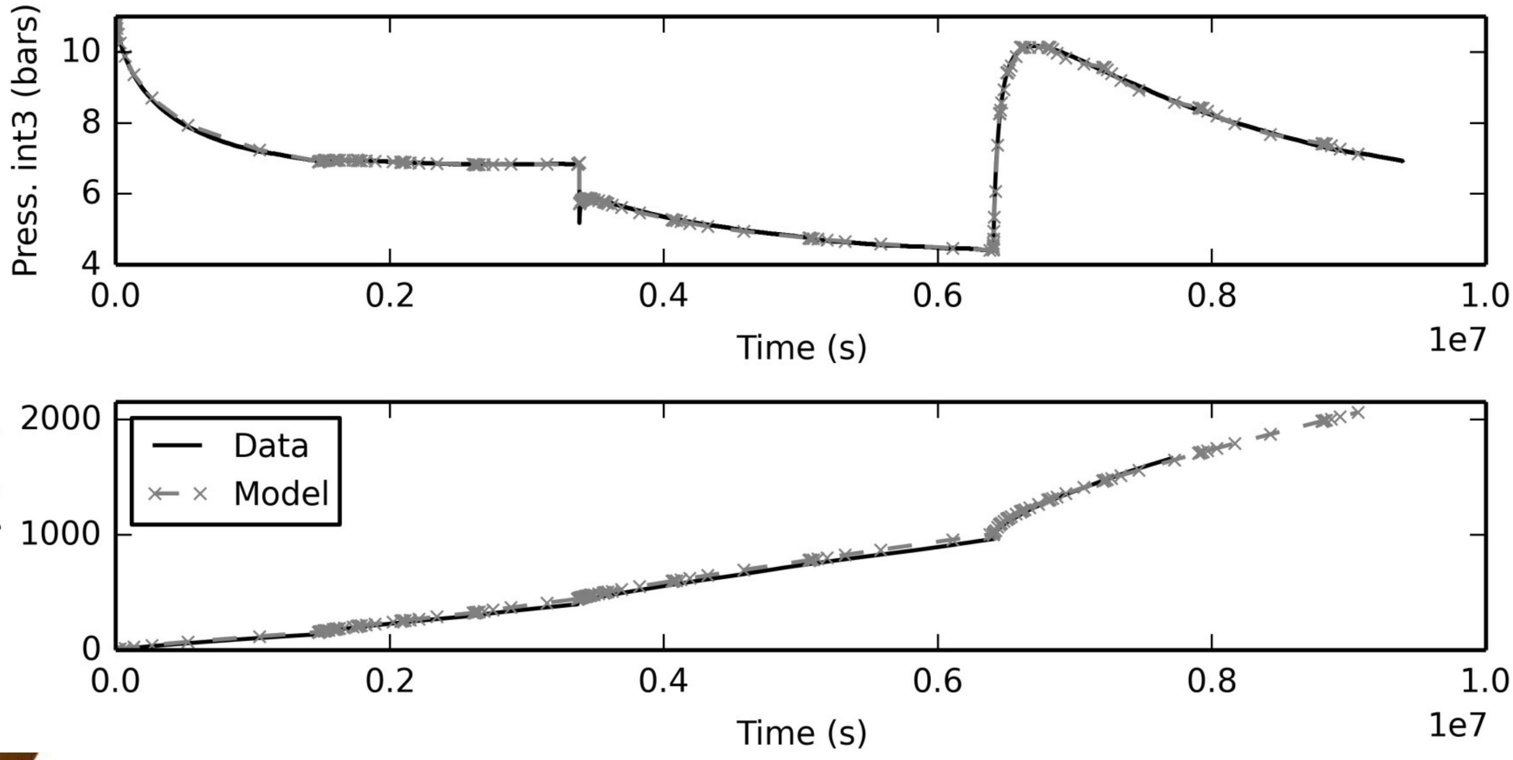
- 2D radial flow modeling (TOUGH2)



- 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

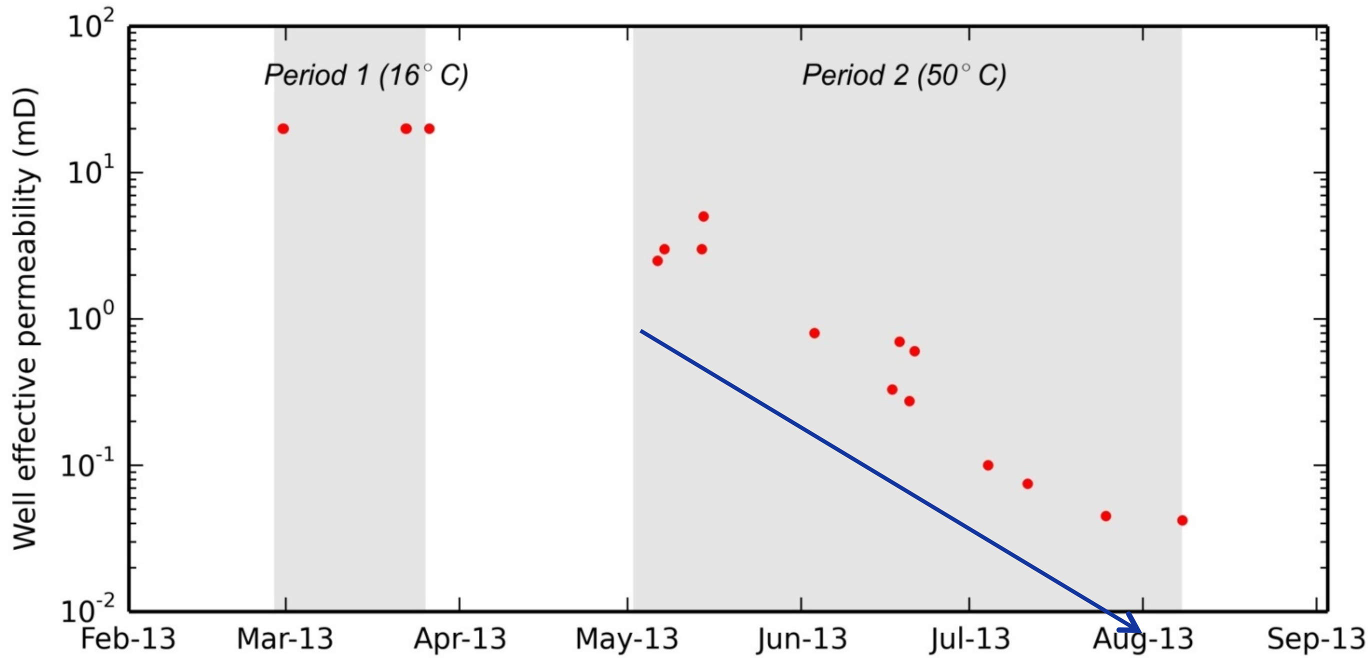
Validation of the hydraulic model

- Data/model matching in terms of Ptop and injected volume (mass balance).



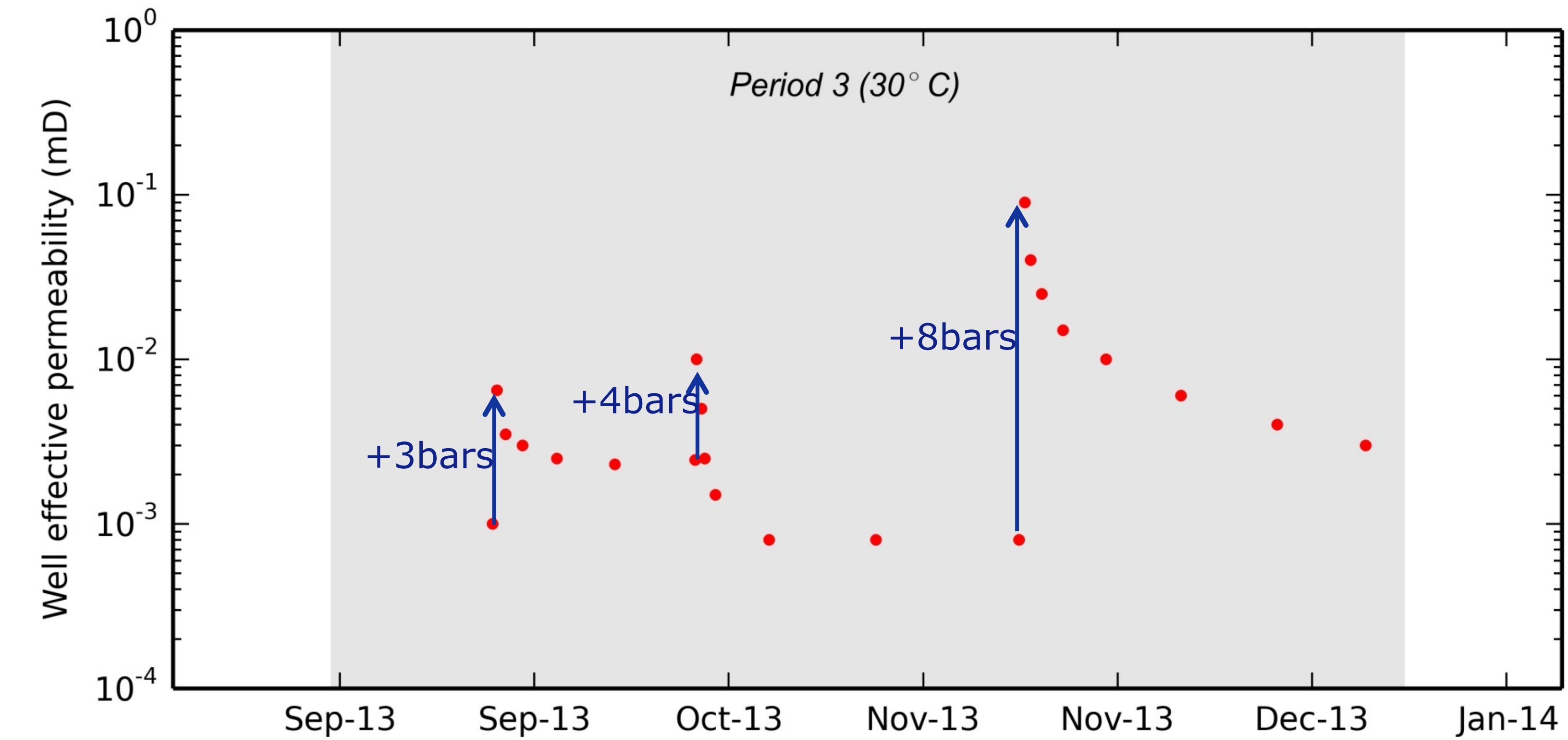
Effects of temperature increase

- A **large decrease of K_{eff}** is observed.
- The bottom interval is disconnected from the caprock/annulus contrary to the top interval: the **K_{eff} decrease** seems to occur **at the bottom (larger T increase)**
- **Rock/material expansion** or **geochemical precipitations or natural borehole convergence** could be contemplated



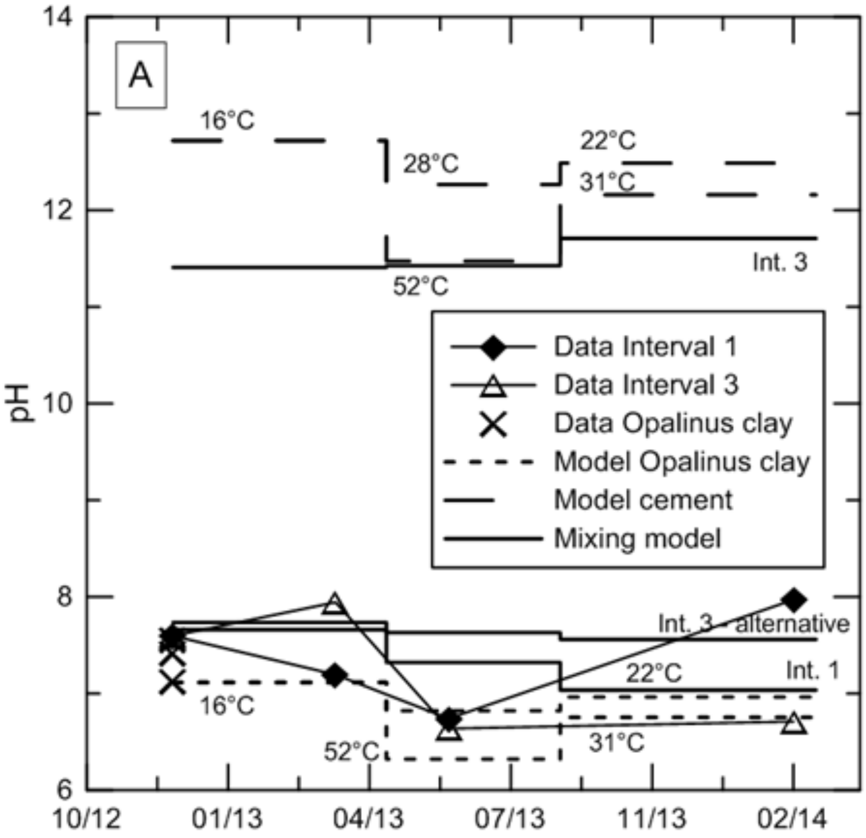
Effect of P_{bottom} increase

- K_{eff} dependant on P_{bottom}: could be a sign of flow



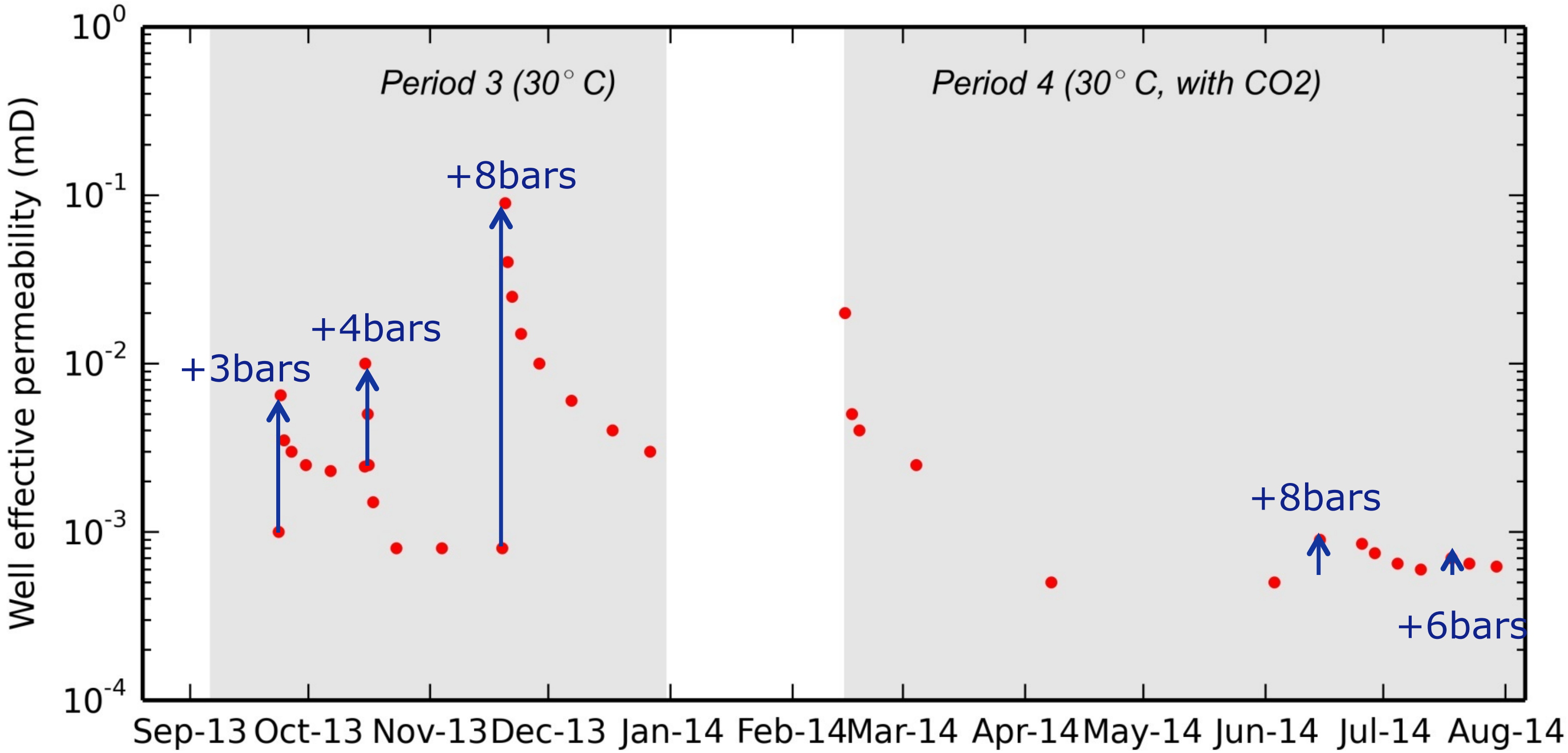
Flow through annuli/interfaces: insights from water chemistry

- Solutions from intervals sampled over time
- Geochemical model using PhreeqC v3 which simulates the **water/cement/clay interactions** and the **transport**
- Solution composition in top interval could be explained by a **channelized flow** without passing through the cement porosity



Results: effects of CO_2

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



Conclusions

- **Ability** of the chosen design 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 planned to last until spring 2015
- **Final overcoring**: link these preliminary observations with mineralogical observations

Thank you for your attention

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